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ETUDE GEOTHERMIQUE PRELIMINAIRE DU NE ESPAGNOL

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Le NE de la Péninsule Ibérique présente une série de caractéristiques géologiques particulières qui ont conduit à effectuer une étude à l'échelle régionale de ses possibilités géothermiques. Ce travail a eu pour but d'établir une première évaluation des possibilites existantes dans la région, et de fixer une échelle de priorités entre les diverses zones étudiées auxquelles on pourra appliquer par la suite des méthodes de prospection plus positives.

L'étude a embrassé toute la Catalogne et représente une étendue approximative de 40.000 km2. Les critères qui ont motivé la sélection de cette zone ont été les suivants:

- L'existence de 19 localités avec des sources thermales dont la température oscille; entre 20º et 71ºC.

- L'apparition d'eau chaude (40º-55º) dans 4 sondages, l'un desquels à peu de profondeur (50ºC à 160 m, etc).

La partie la plus orientale de la Catalogne fait partie du système distensif de la Méditerranée occidentale qui agit depuis le Miocène jusqu'au moment actuel, avec d'importantes manifestations volcaniques de l'âge plio-quaternaire.

- L'importante activité sismique localisée dans ces zones distensives.

On a pris comme point de départ l'inventaire des manifestations thermales superficielles, en considérant comme telles celles dont la température dépasse de 5ºC la moyenne annuelle de la région (15ºC) et, par conséquent celles des autres points d'eau souterraine environnants. En conséquence, on a considéré que les eaux sont thermales à partir de 20ºC.

1.- GEOLOGIE.-

Les manifestations thermales superficie

lles apparaissent dans deux unités morphostruc turales bien différenciées: Pyrénées et Catalanides, et toujours sous la forme de sources d'eau chaude dont la température atteint 71ºC. La dépression de l'Ebre, dans sa zone catalane, ne présente pas ces manifestations.

La répartition des sources thermales - dans les Pyrénées est irrégulière, car elles se trouvent avec une plus grande profusion -- sur la versant française que sur l'espagnole, et c'est sur celui-ci qu'elles sont situées - presque en totalité sur la partie orientale - de la cordillère, depuis Panticosa (Huesca) - jusqu'à la Méditerranée.

Les manifestations thermales sont disposées, dans les Pyrénées, en 3 grands centres: un occidental associé au massif granodioritique de la Maladeta et aux zones adjacentes - (Lés, Arties, Tredós, Bohi, Espot), un autre central se rattachant au massif intrusif d'An dorre (Les Escaldes, S. Vicente, Senillers) - et un dernier oriental associé au massif également granodioritique de la Junquera (Notre-Dame des Mercedes, S. Clemente).

Les sources thermales sont localisées, dans tous les cas, dans des fractures périphé riques de ces massifs, soit intérieures au -- corps intrusif ou incorporées aux matériaux - paléozoïques qui constituent leur bord, bien que toujours à proximité de ce contact.

La seconde grande unité morphostructurale avec des manifestations thermales est cons tituée par les Catalanides, système intégré par 2 chaînes montagneuses de direction NE-SO parallèles à la côte, séparées par une fosse tectonique intermédiaire de 10 à 20 km de lar geur et environ 250 km de longeur avec rempli ssage mio-pliocénique.

Les sources chaudes apparaissent situées sur les lignes de faille qui constituent les limites de cette fosse distensive. A sa termi naison septentrionale, apparaissent les premiè res manifestations volcaniques de l'âge pliocène qui se déplacent, dans l'espace et dans le temps, vers le Nord jusqu'à atteindre leur point culminant dans la région de volcanisme quaternaire (0,11 M.A.) d'Olot.

L'inventaire effectué quant aux mouvements sismiques, un historique de 1100 à 1906, l'autre instrumental de 1907 à 1974, révèle - une coincidence notable spatiale entre la sismicité et le thermalisme, de façon que les -- centres qui montrent des manifestations thermales sont aussi des zones de préférence à localisation d'épicentres. Tandis que dans les Pyrénées, les deux phénomènes se groupent dans les zones périphériques des massifs granodioritiques intrusifs et dans les dépressions -- tertiaires intramontagneuses, dans les Catalanides, ils se disposent dans les failles di-- rectrices de distension alpine qui déterminent la morphostructure régionale.

2.- REGIME THERMIQUE ET HYDRAULIQUE.-

Dans le but d'essayer de connaître le comportement hydrogéologique des eaux thermales, on a établi un contrôle périodique des - régimes thermiques et de décharge des sources sous un double aspect: à niveau bibliographique en comparant les données d'áutres époques avec les temps actuels et, ensuite, au moyen de mesures périodiques de débits et de températures dont il a été possible d'établir ces déterminations (contrôle mensuel pendant 3 - ans: 1972-1975).

Les températures de sortie oscillent - entre la limite du thermalisme préfixé (20ºC) jusqu'à 71ºC, bien que la limite de variation la plus courante soit entre 30 et 60ºC.

Il faut préciser que la température reste constante et invariable face aux variations climatiques et saisonnières. Elles n'ont pas - non plus montré de variation importante depuis les premières données que l'on possède (fin du XIXe S. commencement du XXe) jusqu'à ce jour.

Les débits des sources ont également - présenté une stabilité marquée pendant les 3 années où elles ont été jaugées périodiquement puisqu'il n'a pas été observé de changements - saisonniers ni d'altérations dans leur régime de décharge devant les pluies intenses ou les sécheresses prolongées.

Si pour faire des calculs, nous supposons ces sources faisant partie d'un régime - hydraulique non influencé, il est facile de - déduire que leur comportement hydrologique -- obéit à un modèle où la recharge et/ou le --- stockage sont très supérieurs à la décharge, la transmissibilité étant, au moins celle du circuit de départ, également réduite, puisque son régime ne répond à aucune loi exponentielle de tarissement.

Afin de quantifier le temps de permanence des eaux thermales en profondeur, on a procédé à l' analyse de leur contenu en tritium. Les résultats obtenus oscillent entre - 0,0 ± 1,3 U.T. et 16,5 ± 1,6 U.T., bien que - les valeurs les plus normales soient comprises entre 0,3 et 6,5 U.T. Les concentrations sont donc suffisamment basses pour faire penser qu'elles ne correspondent pas aux apports des dernières 20-25 années, ni mettre en évidence des mélanges avec des eaux météoriques récentes.

3.- HYDROCHIMIE.-

On a effectué deux campagnes d'échantillonnage chimique qui, en même temps que d'autres analyses déjà faites, ont démontré la - stabilité chimique totale que présentent les eaux thermales. A titre d'exemple, on donne - plusieurs analyses de Caldes Montbui (71ºC) - (Tableau I).

Sauf dans quelques cas, tout le thermalisme du NE espagnol est associé à des matériaux granitiques. Dans les occasions où la - circulation de l'eau est réalisée par des materiaux sédimentaires, les eaux présentent la composition chimique qui correspond aux roches par lesquelles le parcours a été établi.

Les autres eaux thermales, qui constituent le groupe majoritaire, se trouvent en - rapport avec des granodiorites et présentent une faciès bicarbonaté-sodique très constante qui est caractérisé par des teneurs élevées -

TABLEAU-I

	Oliver Rodes (1910)	Oliver Rodes (1935)	Albert (1972)	Trilla (1973)	Albert (1974)
CO_3H^-	209,6	138,6	155,2	157	148,1
$SO_4^=$	48,1	51,9	45,1	47,2	47,8
Cl^-	547,4	539,9	539,6	520	536,4
SiO_2		103	84,5	60	90,0
Na^+	412,4	434,4	397,5	400,0	398,1
K^+	26,7	28,7	20,8	20,0	20,2
Mg^{++}	0,4	0,5	1,4	0,3	0,9
Ca^{++}	25,6	26,1	23,2	26,0	22,6

en SiO_2 (jusqu'à 215 ppm), des pourcentages - de Na^+ supérieurs à 90% et un contenu réduit en sels (100-300 p.p.m de T.D.S). Ce fait, - joint à la prédominance totale du Na^+ sur les autres cations, conditione des valeurs très - petites de dureté, (0,4 - 2ºF).

En comparant les analyses chimiques de ces eaux thermales avec celles des eaux superficielles pour une même zone, on constate dans tous les cas le même fait: tandis que les eaux d'écoulement ou de circulation souterraine peu profonde sont bicarbonatées-calciques, avec - une teneur en silice qui depasse rarement 15 ppm, et des concentrations de Na^+ en général inférieures à 25%, les thermales subissent un acroissement notable de ces éléments, ce qui donne lieu à la composition chimique précédemment indiquée. Le phénomène est général pour toute la Catalogne.

La justification chimique du phénomène décrit est attribuée à un équilibre entre le système albite-anorthite et l'eau thermale -- qui libère du Na^+ et de la silice.

$$\underset{\text{Albite}}{2\ Si_3O_8AlNa} + Ca^{++} + 8H_2O \rightleftharpoons$$

$$\rightleftharpoons \underset{\text{Anorthite}}{Si_2O_8Al_2Ca} + 2Na^+ + 4SiO_4H_4$$

La réaction en question a été étudiée expérimentalement par ORVILLE (1972) et a été appliquée aux basaltes de la zone géothermique de la Somalie française par LOPOUKHINE (1973). Dans le cas qui nous intéresse, elle est appliquée pour la première fois à des processus -- thermiques associés à des roches granitiques.

4.- THERMOMETRIE HYDROCHIMIQUE.-

Un chapitre important de la prospection géothermique, c'est l'application des diverses techniques existantes pour estimer la température en profondeur qui a été celle du dernier équilibre entre l'eau et la roche, indépendamment d'une température quelconque de sortie.

Pour chaque eau thermale, on a calculé les geothermomètres suivants:

- SiO_2
  a) graphiques de FOURNIER et TRUESDELL (1970)
  b) équation de SIEVER (1962)
- Na/K: courbe moyenne d'ELLIS (1970)
- Na-K-Ca: méthode empirique publiée par FOURNIER et TRUESDELL (1973).

Cependant, et d'après le raisonnement chimique effectué au paragraphe précédent pour justifier le caractère bicarbonaté sodique des eaux thermales provenant de granites, si on constate en réalité la réaction d'équilibre proposée, son traitement thermodynamique doit être un autre géothermomètre spécifique dont les résultats doivent coïncider avec ceux mentionés plus haut.

La méthode consiste à calculer la valeur de la constante d'équilibre de la réaction mentionnée pour une ample gamme de températures comprises entre 25 et 300ºC, à partir des chaleurs de réaction des éléments réactifs. L'expression de la constante d'équilibre

$$K = \frac{\left[A_{Ca^{++}}\right]}{\left[H_4\ SiO_4\right]^4 \left[A_{Na^+}\right]^2}$$

peut s'écrire

$$\log K = \log \frac{\left[A_{Ca^{++}}\right]}{\left[H_4\ SiO_4\right]^4} - 2 \log \left[A_{Na^+}\right]$$

ce qui fait que l'on peut construire un diagramme $\log \frac{\left[A_{Ca^{++}}\right]}{\left[H_4\ SiO_4\right]^4}$ en fonction de $2 \log \left[A_{Na^+}\right]$ où la valeur de chaque constante d'équilibre pour chaque température sera exprimée par une droite de valeur log K.

Afin de ne pas trop allonger ce résumé on peut trouver son développement dans les travaux de LOPOUKHINE (1973) et d'ALBERT (1975).

Sur le tableau II, on indique quelques-uns des résultats obtenus, à titre d'exemple, avec les différentes méthodes. Comme les résultats dérivés de l'application de l'étude thermodynamique de l'équilibre albite-anorthite coindicent avec les géothermomètres classiques, on peut considérer comme valable la justification chimique du caractère bicarbonaté sodique exposé ci-dessus.

Etant donné les ordres de grandeur rencontrés (80º - 120º), on peut conclure qu'il ne faut pas s'attendre à trouver en Catalogne des gisements géothermiques d'une enthalpie élevée, pour le moins déductibles à partir de manifestations superficielles.

5.- GRADIENTS GEOTHERMIQUES CALCULES PAR DES SONDAGES PETROLIFERES.

Dans cette phase de prospection initiale, on a calculé les gradients géothermiques de 18 sondages pétrolifères à partir des valeurs de BHT (bottom-hole temperature) recueillies dans les logs électriques à des profondeurs diverses.

Cependant, les températures mesurées dans les sondages au moyen d'un enregistrement électrique ne correspondent pas à la température réelle de la formation à cette profondeur, sinon qu'elles adoptent généralement des valeurs plus basses par l'effet de la circulation de la boue, puisque la mesure est effectuée après avoir sorti la tige sans attendre la stabilisation thermique. En général, le temps qui doit s'écouler entre la fin de la circulation de la boue et son équilibre thermique avec la formation est de 40 à 50 heures.

En conséquence, les mesures de température recueillies dans les logs. électriques ont été corrigées jusqu'à leur stabilisation thermique en suivant la méthode de FABIAN (1955), ce qui a permis d' obtenir un ordre de grandeur beaucoup plus proche des valeurs réelles des gradients géothermiques en utilisant uniquement des puits déjà perforés.

Les valeurs obtenues aprés la correc-

LOCALIDAD	Temp. agua manantial (ºC)	SiO_2 (ppm)	$\frac{r\,Na}{r\,K}$	GEOTERMOMETRO SiO_2		GEOTERMOMETRO	GEOTERMOMETRO	EQUILIBRIO	Contenido de Tritio (U.T.)
				Fournier	Siever	Na/K	Na-K-Ca	ALBITA - ANORTITA	
CALDES DE BOI									
Termas romanas	50º	73	49,0	117º	108º	99º	91º	103º	4,3 ± 1,4
Banys	45º	67	53,6	114º	106º	92º	95º	108º	3,8 ± 1,4
S. CLEMENTE	23º	34	92,6	85º	72º	66º	63º	65º	0,6 ± 0,8
CALDES DE MONTBUI	70º	84	32,6	124º	117º	127º	143º	120º	2,2 ± 1,4
CALDETES	38º	46	66,7	97º	85º	81º	84º	81º	7,0 ± 0,6

TABLEAU II

tion sont toujours supérieures à celles mesurées directement, excepté dans le cas des enregistrements à moins de 600 m, alors que les gradients s'intervertissent parce que la pente de la droite log température - log temps est négative. Les limites extrêmes trouvées sont 0,24 et 0,72ºC/10 m, ce qui correspond à des valeurs de flux comprises entre 1,5 et 4,4 HFU, bien que les ordres de grandeur les plus fréquents oscillent entre 0,30 et 0,50ºC /10 m (1,8 et 3,0 HFU).

Les valeurs minimales correspondent à la partie centrale de la province de Lérida, dans la zone délimitée par les rivières Segré et Noguera Pallaresa avant leur confluent, et elles augmentent peu à peu vers les Pyrénées et les Catalanides, toujours en direction des grandes fractures NE-SO qui déterminent le processus de distension actuel.

Les gradients trouvés de cette manière bien qu'ils ne soient pas exacts, procurent un ordre de grandeur acceptable qui permet de quantifier le phénomène, en même temps qu'ils nous indiquent que la profondeur à laquelle s'établit l'équilibre calculé par des géothermomètres chimiques ne dépasse pas 1000 m. audessous du niveau de la mer.

Cette étude a permis de sélectionner les zones qui, du point de vue thermique et de la qualité des eaux, présentent le plus grand intérêt. Actuellement, l'Institut Géologique et Minier d'Espagne, par l'intermédiaire de la Compañia General de Sondeos, a abordé l'étude concrète, au moyen de la géophysique et de mailles de sondages thermométriques d'une des zones qui apparaissent comme étant les plus favorables.

Cette zone, située à environ 30 km au NO de la ville de Barcelone, est située sur la ligne de faille occidentale qui limite la grande fosse tectonique distensive des Catalanides parallèle à la côte, et dont le saut se chiffre approximativement par 4000 m.

Telle que manifeste la sismique pétrolière qui se réalise sur la plate-forme conti nentale méditerranéenne, en face des côtes du Levant espagnol, la fosse des Catalanides susmentionnée où a commencé la prospection géothermique en Espagne, n'est que l'affleurement continental d'un vaste système distensif de horsts et de grabens de direction parallèle à la côte méditerranéenne espagnole qui se prolonge au moins jusqu'aux îlex Baléares. Ce système est affecté par une activité volcanique abondante de l'âge plio-quaternaire qui atteint une importance notable dans la province de Gérone, ainsi qu'un développement appréciable sur la plate-forme continentale elle-même.

Actuellement, on est en train de corriger, à l'aide de la méthode mentionnée ci-dessus, les logs électriques de plus de 50 sondages pétrolifères, la plupart d'entre eux marins, répartis tout au long de la côte méditerranéenne espagnole, afin de quantifier la valeur des gradients existants dans cette intéressante zone de tectonique récente.

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THE USE OF M.T.-5-E.X. MAGNETO TELLURIC IN GEOTHERMAL EXPLORATION

by

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I - INTRODUCTION

M.T.-5-E.X. is a magneto-telluric exploration tool which has been developed by Dr. Louis MUSE, Magnetic Prospecting Inc.

Investigations leading to the design of new magneto-telluric measuring devices started in the early sixties for the S.N. REPAL in Algeria, in connection with petroleum exploration problems, and was continued later in France in the framework of the BEICIP (Bureau d'Etudes Industrielles et de Coopération de l'Institut Français du Pétrole). Since three years this method has been employed by service companies in France (SPEM) for operations in the Eastern Hemisphere and in the USA (GEMPS) for the Western Hemisphere.The newest process, M.T.-5-E.X. is now in operation since 1972 with a few modifications. This process involves specially designed measuring instruments and new recording and processing methods.

The M.T.-5-E.X. magneto-telluric method uses suitable field devices to provide for digital recording of variations of the natural electric field in two directions (Ex and Ey) and of variations of the magnetic field in both these directions (Hx and Hy) plus the vertical Hz.

The signals from the recor ing channels are digitalized simultaneously by two independent recording mini-cassette systems in order to insure reliability. A monitor accompanies the two digital recorders and gives an analog record.

The electro-magnetic variations recorded are represented by a spectrum conventionally defined by $f < 1$ hertz, the lowest usable frequency being related to the duration of the recording.

In the field the five components are recorded graphically (for visual control) and numerically on magnetic tape with specifically designed

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and patented recording instruments. The magnetic tapes are processed by means of a computer program, using exponential solutions, in GEMP's Santa Rosa (California) processing center.

The processing of the field records involves a new concept in analysis. The signals are initially processed so as to be regarded as sums of real exponentials and the processing uses exponential solutions to the equation of MAXWELL rather than the conventional harmonic solution.

The processing is highly sophisticated and the computer program requires the use of a CDC 7600 computer. The subsequent interpretation involves the comparison and the adjustment of the processing results with theoretical caluculations based on geological data and eventually on electric logs of available boreholes.

The results are furnished in function of various periods of τ, time-constant, and not of various periods of T as in harmonic analysis. In M.T.-5-E.X. the low frequencies are used because this method is aimed at knowing with precision the characteristics of reservoirs at depth, without preoccupation for hhe superficial formations and without trying to obtain structural details which in a general way c nnot be obtained with accuracy by means of electric resistivity measurements.

As a function of the various values of τ the processing of the magnetic tapes in a CDC 7600 computer gives the main trend, the apparent resistivities according to the x and y directions as well as other values which allow to determinate whether the structure is tabular, cylindrical or even more complex.

From the resistivity values, the resistivity curves as a function of are traced automatically. The final interpretation uses all these data and leads to the drafting of longitudinal iso-conductance maps, of apparent vertical resistivity maps and of a main trend map.

Before deciding if a M.T.-5-E.X. program can be successfully carried out it is necessary to make a preliminary study of the geological information of the area and of the know results of eventual deep boreholes, i.e. to furnish a precise geological definition of the problems to be resolved with M.T.-5-E.X.

M.T.-5-E.X. resolves rather satisfactorily the problem of cylindrical and tabular geological structures, starting with the main trend of cylindrical structures, on condition that the various geological formations represented do not have all the same resistivity.

Field operations depend on local conditions. The recording equipment powered by two ordinary car batteries is mounted in two four-wheel drive vehicles, whereas in areas of difficu t acces portable equipment is used. A field crew is usually composed of 4. Under normal conditions a field crew can make 2 to 4 stations per day.

M.T.-5-E.X. has been used in petroleum exploration and since 1972 also in geothermal exploration. It has shown to be able to help determine with accuracy the subsurface presence of porous and permeable formations filled with hot or cold saline water, or steam and to defferentiate between oil and water-filled reservoirs.

II - M.T.-5-E.X. IN PETROLEUM EXPLORATION

Whenever possible a M.T.-5-E.X. survey should be preceded by a review of the available well-records, in order to calibrate the method for the area of investigation. Magneto-telluric measurements outside de drilled area then provide geologists and reservoir engineers with essential data for the appraisal and development of the area.

This method provides for accurate mapping of conductor formations. It is for instance possible with M.T.-5-E.X. to defferentiate between the porous and non-porous parts of known petroliferous reef-formations, on condition that the reef has a sufficient thickness and that the pores are filled with salt water and/or oil and gas. The same differentiation is possible for thick sandstone formations.

Successful surveys have been carried out in Algeria, Tunesia, France, Canada and the USA.

III - M.T.-5-E.X. IN GEOTHERMAL EXPLORATION

Highly successful in petroleum exploration M.T.-5-E.X. appears even more specifically adapted to geothermal problems.

Hitherto the more conventional electric sounding and induction methods have been used to detect resistivity anomalies, based on the principle that high temperature permeable formations show low resistivities.

In seeking such low resistivity zones M.T.-5-E.X. measures the apparent resistivity of the underlying formations at each recording station as a function of the natural electro-magnetic spectrum. Various parameters used for interpretation, n otably conductance, can be calculated from these measurements. Conductance is higher when the beds are thick and of low resistivity.

Results in various areas in the world have shown that in the low frequencies, the apparent resistivity variations are highly distinctive between cold or tight zones and those productive of geothermal fluids.

Conventional magneto-telluric methods, presently currently used in geothermal exploration have so far been considered adapted to broad and medium scale reconnaissance. The results obtained by M.T.-5-E.X. indicate that this method is particularly suited to detailed problems in geothermal exploration, although equally well adapted to general reconnaissance.

M.T.-5-E.X. was first used as a geothermal prospecting tool in Tuscany (Italy) in the Travale area, east of the Larderello geothermal field, in 1973, after the successful completion of the Travale n° 22 well which produced approximately 800.000 pounds od dry steam and non-condensable gas per hour from Triassic carbonates at 2200 feet depth. This investigation was first carried out on behalf of the National Research Council of Italy in the framework of the International Institute for Geothermal Research in Pisa and subsequently for the ENEL (Italian National electricity authority).

Stations were initially laid out at an average spacing of 800 meters over an area of about 30 sq.km., which included the old Travale field. In 1976 a series of closely spaced stations was laid out, mostly in the southwestern part of the area of investigation.

Stations in the southern part of the area, where surface carbonates are associated with a cold zone, indicated main trends with the usual NW-SE strike of the allochtonous nappe formation, whereas measurements made further north revealed a swing of the main trends to NE-SW. Thus, whereas the Travale area has usually been considered as a NW-SE striking graben, M.T.-5-E.X. has shown that the narrow zones with permeable reservoir conditions indicated by very high conductances, were perpendicular to this direction i.e. NE-SW.

The M.T.-5-E.X. survey clearly indicated that Travale n° 22 was sited on a strong longitudinal conductance anomaly and it also indicated that the projected Radicondoli n° 1 and n° 2 boreholes were located in zones of high resistivity and therefore unlikely to produce geothermal fluids. As a matter of fact neither Radicondoli n° 1 nor n° 2 did encounter any geothermal fluid due to lack of permeability, but found dry hot rock only.

Following the M.T.-5-E.X. survey the Radicondoli n° 3 and n° 4 were drilled, both located in highly conductive anomalies. Radicondoli n° 3 encountered the Triassic resarvoir at 720 meters depth with unexpectedly high temperatures (280°C) and with a high productivity. Unfortunately the well could not be put in production due to technical incidents. The Radicondoli n° 4 well was located on a similar anomaly and encountered the Triassic reservoir at a depth of 1365 meters. This well made 350 000 pounds of dry steam and carbon-dioxide.

In the latter part of 1975 and in 1976 detailed surveys were run over the Travale and Torre Alfina geothermal fields, in order to help siting further development wells.

On the French Caribeanisland of Guadelupe a M.T.-5-E.X. survey was carried out at the end of 1973, in the area surrounding the Bouillante geothermal field discovery. At Bouillante this survey indicated a very strong conductive anomaly in the neighbourhood of the discovery well. This anomaly is small in size. Similar N-S striking anomalies were found in the same area, all rather narrow. The most interesting anomaly at Bouillante has not been drilled yet due to logistical difficulties.

After these first M.T.-5-E.X. surveys, other geothermal exploration surveys have been carried out with it in Italy, Southeast Asia and the western USA. At present one party is involved in a survey in Kenya.

Electric sounding with direct current input and various devices (dipole or quadripole) are commonly used in geothermal exploration and they are useful for general reconnaissance. These methods require increased electrode spacings in order to obtain increased penetration and the spread may reach several kilometers. In magneto-telluric methods on the other hand,the depth of penetration can be increased by recording and analysing the slowest variations (skin effect). The equipment spread does not have to be increased. As a matter of fact M.T.-5-E.X. electrodes are only 100 meters apart.Electric soundigs required hauling around long and heavy lengths of cable and bulky generators, whereas M.T.-5-E.X. operates on ordinary car batteries.

Compared with the standard magneto-telluric investigation methods M.T.-5-E.X. offers several advantages. It is a tri-dimensional method capable of determining the main trends and subsurface discontinuities, as well as the total conductance in the geological direction. It gives a practical solution to the problem of the terrestrial electro-magnetism in the case of cylindrical structures, due to the analytical method used, whereas the quality of the curves is greatly improved.

Also for a same depth of investigation it is possible to take measurements over a much shorter period of time with M.T.-5-E.X. than with the more conventional magneto-tellurics.

Electro-magnetic or induction methods are also widely used in geothermal prospecting. They require usually the input of alternative current. As in magneto-tellurics the electro-magnetics uses the subsurface propagation of electro-magnetic waves and the skin-effect phenomenon. However their usable spectrum is not sufficient in the low frequencies and their technological capacity is limited. The depth of investigation for electro-magnetics is therefore much more limited. The generated waves are not planar, which hinders quantitative interpretation in the case of a complex structure.

It therefore appears that the.-5-E.X. magneto-telluric as an exploration tool is particularly well adapted to geothermal problems and can be profitably used in general reconnaissance in stead of the usual resistivity surveys and is the ideal tool for detailed exploration.

IV - REFERENCES

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MINISTERIO DE INDUSTRIA Y ENERGIA

INSTITUTO GEOLOGICO Y MINERO DE ESPAÑA

ESTUDIO MAGNETOTELURICO Y AUDIO - MT DE LAS ANOMALIAS GEOTERMICAS DE CALDES DE MONTBUI Y LA GARRIGA.-

rasgos = features

1.- ANTECEDENTES

The geothermal prospection by resistivities, middle SEV, carrying to end by the IGME during 1976 defined the existence of the anomaly of Caldes and La Garriga. This phase put of manifest furthermore other interesting features of surface to the plans of new investigations. One of them is the existence of resistivity formations in the zone next to the western fault. These materials, conglomerates, present an irregular distribution, its depth oscillating around those of 300-500 m.

La prospección geotérmica por resistividades, mediante SEV, llevada a cabo por el IGME durante 1976 definió la existencia de las anomalías conductoras de Caldes y La Garriga. Esta fase puso de manifiesto además algunos rasgos interesantes de cara a la planificación de nuevas investigaciones. Uno de ellos es la existencia de formaciones resistivas en la zona próxima a la falla occidental. Estos materiales, conglomerados, presentan una distribución irregular oscilando sus profundidades alrededor de los 300-500 m.

The conclusion of the evaluation of the anomaly in depth is of the major interest in the actual state of investigation of the geothermal possibilities of the Vallés. lowlands

El conocimiento de la evolución de la anomalía en profundidad es del mayor interés en el estado actual de investigación de las posibilidades geotérmicas del Vallés.

Apart from this brings of obtaining information about the geometry of the basement base of the depression of form that is able to support or to confirm the data resulting from the gravimetric survey used by the IGME

Aparte de esto se trata de obtener información sobre la geometría del basamento de la depresión de forma que se puedan apoyar o confirmar los datos resultantes de la campaña gravimétrica llevada a cabo por el IGME.

As methods adequate to these finals have proposed the and giving that they permit to make a recognition to profound differences in function of the frequency analized

Como métodos adecuados a estos fines se han propuesto el Magnetotelúrico (MT) y Audiomagnetotelúrico (AMT), dado que permiten hacer un reconocimiento a diferentes profundidades en función de la frecuencia analizada.

The whole of the work has been realized by the having been contacte for its execution with the colaberation of The planning of the work thus as the interpretation of the results have experienced the loading of as responsible for the Project.

El conjunto del trabajo ha sido realizado por la Compañía General de Sondeos habiendo contado para su ejecución con la colaboración de D. Ramón Ortíz Ramiz y D. José Luis Díez Gil, Doctores en Ciencias Físicas. La planificación de los trabajos así como la interpretación de los resultados ha corrido a cargo de D. Angel Granda Sanz, Ingeniero de Minas de la Compañía General de Sondeos, como responsable del Proyecto.

4.- TRABAJOS REALIZADOS

With the equipment of MT measured 40 stations distributed
Con el equipo de MT se midieron cuarenta estaciones dis
regularly through the zone of work. With objective
tribuidas regularmente por toda la zona de trabajo. Con obje-
of being able to support the results obtained through
to de poder apoyar los resultados obtenidos mediante audio-MT.
The time of execution of the readings is very variable depending
El tiempo de ejecución de las lecturas es muy variable depen-
on the characteristics of each station. Each day
diendo de las características de cada estación. Cada día se
brought a control of the data measured its demodulation and
llevó un control de los datos mediante su demodulación y re-
graphicly registered with the object of evaluating its heat and in its case
gistro gráfico con objeto de valorar su calidad y en su caso
to repeat the lectures until that its value was satisfactory.
repetir las lecturas hasta que su validez fuera satisfactoria.
The treatment posterior of the magnetic bands did not result factually,
El tratamiento posterior de las bandas magnéticas no resultó
to these previsions, in 10 station by it that
factible, pese a estas previsiones, en diez estaciones por lo
only included 30 MT soundings
que solo incluimos 30 sondeos MT.

sondeos = drill holes or sounds

The measurements of audio-MT distributed about perpendicular
Las medidas de audio-MT se distribuyeron sobre perfiles
profiles to the plan of the western fault of the Vallés,
perpendiculares a la traza de la falla occidental del Vallés,
with the following soundings by profile
con los siguientes sondeos por perfil.

Profile				soundings
Perfil	0	-	5	sondeos
"	1	-	9	"
"	2	-	11	"
"	3	-	12	"
"	4	-	5	"
"	5	-	7	"
"	6	-	10	"
"	7	-	8	"
"	8	-	5	"
"	9	-	10	"
"	10	-	8	"
"	11	-	8	"
"	12	-	8	"
"	13	-	9	"

Before finalizing this part we go to comment a
Antes de finalizar este apartado vamos a comentar un
significant fact. We represent in skematic form all
hecho significativo. Representamos de forma esquemática to-
the families of group 1 (Fig. 3). If we construct the
das las familias del grupo 1 (Fig. 3). Si construímos las -
lines of connection of the extremes values,
rectas de enlace de los valores extremos, γ_1, γ_2.......γ_9
we can prove that the corresponding to all the curves
podemos constatar que las correspondientes a todas las cur-
sited outside the pit of the Vallés have pending positive
vas situadas fuera de la fosa del Vallés tienen pendiente po
while that is of contrary sign the corresponding
sitiva mientras que es de signo contrario la correspondien-
to the curves within the depression.
te a las curvas de dentro de la depresión.

Pseudosections -
5.2.2.- Seudosecciones.-

Following the definition of Cagniard the apparent resistivity
Siguiendo la definición de Cagniard se ha calculado la
of separation of the octogonal components of the
resistividad aparente a partir de las componentes octogonales
electric and magnetic field, can be calculated according to the
del campo eléctrico y magnético según la formula
formula:

$$\rho_a = K(f)\left(\frac{Ex-Eo}{Hy-Ho}\right)^2 \cdot \frac{1}{\rho^2}$$

K being a constant of calibration of the coil, f the frequency
siendo K una constante de calibrado de la bobina, f la frecuen
in Hz and Eo, Ho characteristic constants of being able to
cia en Hz y Eo, Ho constantes características de puesta a ce-
center of the equipment, and l the distance between electrodes. The program
ro del equipo, y l la distancia entre electrodos. El programa
calculated reproduced to continuation. It Gives the characteristics
de cálculo se reproduce a continuación. Dadas las caracterís-
of the equipment obtaining a range of variation of the apparent
ticas del equipo se obtiene un rango de variación de las resis
resistivities very amplified, between 10^2 and 10^{-8}. With the object
tividades aparentes muy amplio, entre 10^2 y 10^{-8}. Con objeto
of making an intent of comparability of these resistivities
de hacer un intento de comparabilidad de estas resistividades
with the obtained by other methods we have restricted field
con las obtenidas por otros métodos hemos restringido el cam-
of variation by application of the following table:-
po de variación por aplicación de la tabla siguiente:

The mass of the pseudosections obtained are represented
El conjunto de las seudosecciones obtenidas se repre-
in the figures 4 to 12. For its construction have elected
sentan en las figuras 4 a 12. Para su construcción se han ele
arbitrary intervals at 50, 100, 150, 200, etc., ohm.m.
gido intervalos arbitrarios a 50, 100, 150, 200 etc, ohm.m.
We record that all correspond in the principal direction
Recordemos que todas corresponden a la dirección principal -
that is the N-S of the electric field.
que es la N-S del campo eléctrico.

5.2.3.- Modelos de Strangway

It is a variation of the pseudosecciones that permit observation;
Es una variante de las seudosecciones que permite obser
to the same time that lateral variations of resistivity,
var; al mismo tiempo que variaciones laterales de resistividad,
the conditions of to it large of each profile.
las condiciones de anisotropía a lo largo de cada perfil.

For each reading frequencia carry in ordinate,
Para cada frecuencia de lectura se lleva en ordenadas,
corresponding with the vertical of each station, the value of the
correspondiendo con la vertical de cada estación, el valor del
Uniting these values to a large of the line corresponding
$\ln \rho_a$. Uniendo estos valores a lo largo de la línea correspon-
to each frequency obtaining the types of representation
diente a cada frecuencia se obtiene el tipo de representación
that we include in the figures 13 to 30. The shaded zones represent
que incluímos en las figuras 13 a 30. Las zonas sombreadas re-
zones conducted within each profile,
presentan zonas conductoras dentro de cada perfil.

Equal that in the case of the pseudosections we only include
Igual que en el caso de las seudosecciones solo inclui-
the profiles corresponding to the principal direction:
mos los perfiles correspondientes a la dirección principal:
N-S for the electric field
N-S para el campo eléctrico.

The coefficients of anisotropia are calculated by the
Los coeficientes de anisotropía se calculan por la ex-
expression and carry to the diagram of
presión $A = \ln \rho_{N-S} - \ln \rho_{E-W}$ y se llevan al diagrama de for-
analogous form before emitting, Its representation does not specially
ma análoga a lo antes señalado. Su representación no aporta
contribute by it that we only include the correspondence
nada especial por lo que solo incluímos la correspondiente
to the profiles
a los perfiles 0, 1, 3 y 4

maps of isoresistivity
5.2.4.- Mapas de isorresisitividad

Utilizing the data deduced from the audio-MT sounding
Utilizando los datos deducidos de los sondeos audio-MT

we have selected those corresponding to the four fundamental
se han seleccionado los correspondientes a las cuatro frecuen
frequencies:
cias fundamentales: 3800, 490, 39,5 y 8,3 Hz.

If the median lateral discontinuities are able
Si el medio careciera de discontinuidades laterales po-
to make a good estimation of the depth corresponding
dría hacerse una buena estimación de la profundidad correspon
to each one of the frequencies. In our case this is not
diente a cada una de las frecuencias. En nuestro caso esto no
possible by the heterogeneity that characterizes the zone of
es posible por la heterogeneidad que caracteriza la zona de -
study.
estudio.

In these conditions we are not able to assign to the depths
En estas condiciones no podemos asignar a las profundi-
without a median value deduced by statistically treating the
dades sino un valor medio deducido por tratamiento estadísti-
data corresponding to each point These median depths
co de los datos correspondientes a cada punto. Estas profun-
are:
didades medias son:

For meters with standard deviation of
- Para 3800 Hz.- 107 metros con desviación standard de 17,4 m
- Para 490 Hz.- 236 metros con desviación standard de 71 m.
- Para 39,5 Hz.- 890 metros y desviación standard de 301 m.

Here is where the major deviations exist
Es aquí donde existen las mayores desviaciones

For meters and standard deviation of
- Para 8,3 Hz.- 2376 metros y desviación standard de 495 m.

Of equal manner the intervals for the outline
De igual manera los intervalos elegidos para el trazado
of the isolines of resistivity have deduced interceding analog
de las isolíneas de resistividad se han deducido mediante tra
treatment and they correspond to the following values:
tamiento análogo y corresponden a los siguientes valores:

Para 3800 Hz e^{γ} = 157 S= 48

Isolíneas 250, 205, 160, 110, 60

Para 490 Hz e^{γ} = 120 S= 65

Isolíneas 330, 185, 120, 55

Para 39,5 Hz e^{γ} = 130 S= 65

Isolíneas 425, 260, 195, 130, 65

Para 8,3 Hz $e^{\gamma} = 195$ S= 60

Isolíneas 315, 255, 195, 135, 15

The results obtained outline the isolines thus
Los resultados obtenidos trazando las isolineas así de
defined they reflect in the planes that correspond
finidas se reflejan en los planos 3, 4, 5 y 6 que correspon-
respectively to the frequencies of
den respectivamente a las frecuencias de 3800, 490, 39,5 y -
8,3 Hz.

6.- INTERPRETACION DE LOS RESULTADOS

6.1.- MAGNETOTELURICOS

A través del proceso de cálculo descrito en el apartado correspondiente se obtuvieron las curvas que incluimos en los anexos.

Para cada una de ellas representamos los valores deducidos para dos direcciones ortogonales y el valor medio de ambas. Mediante este sistema puede observarse, como cabía preveer, la forma en que las curvas discrepan de la situación ideal por - la existencia de una marcada anisotropía.

El tratamiento de tales curvas es complejo por no ajustarse a modelos sencillos, de los tipos usuales en las colecciones patrón utilizadas.

as standard curves are employed the published collection
Como curvas patrón hemos empleado la colección publica-
by Yungul.
da por Yungul.

To the contrary of those that follow with the
Al contrario de lo que sucede con los Sondeos Eléctricos
in that it can interpret a curve by disarrangement
Verticales, en que puede interpretarse una curva por descompo
in models of two layers the MT soundings have of superimpose
sición en modelos de dos capas, los sondeos MT. han de super-
about theoretical curves of its same number of mantles. In
ponerse sobre curvas teóricas de su mismo número de capas. En
our case this difficult results because the data obtained
nuestro caso esto resulta difícil porque los datos obtenidos
correspond to models of more than three mantles
corresponden a modelos de más de tres capas.
layers

For saving this inconvenient we have secured the major
Para salvar este inconveniente hemos procurado el mejor
adjust about the models of two or three mantles of that disposed.
ajuste sobre los modelos de dos y tres capas de que disponia
We want to signal to this respect that scarcely exist publications
mos. Queremos señalar a este respecto que apenas existen publi
about theoretical curves and method of interpretation,
caciones sobre curvas teóricas y métodos de interpretación.

Of this form the results that we present in the plan 7 has
De esta forma los resultados que presentamos en el plano 7 -
contemplated with many limitations and only of manner
han de contemplarse con muchas limitaciones y solo de manera
indicated by all the negative conditions enunciated
indicativa por todos los condicionantes negativos enunciados

6.2.- AUDIO-MT

6.2.1.- Familias de curvas

Siguiendo una fase previa análoga a la que se efectúa - en la interpretación de SEV tratamos de establecer si las curvas de audio-MT se agrupan en familias de manera coherente - con la situación geológica.

Una vez establecidas las distintas características de - las familias que pueden establecerse situamos cada una de -- ellas sobre el plano a fin de conocer si existe algún agrupamiento que defina anomalías de interés.

Al hacerlo de esta manera pretendemos identificar, en base al conocimiento existente del área, aquellos grupos de curvas dignos de un estudio con mayor detenimiento

Los resultados obtenidos se reflejan en el plano nº 2 y como puede verse no muestran ningún rasgo que haga atractiva la continuación de la interpretación por este camino.

6.2.2.- Seudosecciones

The general aspect of the same have understood exadurated
El aspecto general de las mismas ha de entenderse exage
amplified in its vertical scale. a correspondence exists
radamente ampliado en su escala vertical. Existe una correspon
with the depth that, for the frequency of
dencia con la profundidad que, para la frecuencia de 8,3 Hz,
oscillates between and meters as very frequent values.
oscila entre 1700 y 2400 metros como valores más frecuentes.

En consecuencia las seudosecciones ofrecen una informa ción cualitativa complementaria respecto a la distribución - de resistividades según un corte vertical.

In consequence the pseudosections offer a cualativo information complimentary respect to the distribution of resistivities according to a vertical cut.

Para su construcción hemos considerado intervalos de 50 ohm.m que consideramos suficientes para señalar las caracterís ticas reseñables dentro de cada perfil. Comentaremos brevemente los diversos gráficos que constituyen las figuras 4 a 12.

Como rasgo general de la mayoría de los perfiles se se- ñala una zona central relativamente conductora entre dos de - mayor resistividad que constituyen la parte más superficial y la zona de influencia del basamento. Otro detalle común a muchos de los perfiles es la presencia de una zona conductora - en las cercanías de la falla occidental.

as general stroking of the majority of the profiles signal a relatively central zone conductor between two of greater resistivity that constitute the most superficial part and the zone of influence of the basement. Another common detail to many of the profiles is the presence of a conductor zone in the proximity of the western fault

No existen rasgos de especial relieve dentro de los per files 0 y 1 mientras que dentro del 2 aparece una amplia anomalía conductora centrada alrededor del punto 2.2 y que se extiende en profundidad hasta el 2.7. A esta zona conductora la suponemos en conexión con la anomalía geotérmica ya conocida - en las cercanías de Caldas de Montbuí.

Stroking of relative relief does not exist within the profiles 0 and 1 while that within the 2 appears an amplified conductive anomaly centered around the point 2.2 and that extends in depth until the 2.7. To this conductor zone we suppose it in connection with the geothermal anomaly already known in the proximity of

En el perfil 3, en su zona central, aparece la continua ción de la anomalía anterior con sus menores valores de resis tividad entre los puntos 3-5 y 3-6. Al mínimo de las estaciones 3-0, 3-1 y 3-2 le consideramos ligado a fenómenos geotér micos próximos a superficie.

In the profile 3, in its central zone, appears the continuation of the ~~anterior~~ anomaly with its minor values of resistivity between the points and to the minimum of the stations and we consider ligitating to geothermal phenomenons next to superficial

profile 4

El modelo que representa el perfil 4 es muy simple y res ponde a los rasgos generales de toda la zona mostrando una zona conductora, que se amplía para el rango de 38,5 - 130 Hz. La justificación de esta anomalía ha de estar en la proximidad de la falla más que en cualquier otro fenómeno.

It is admissible to say somewhat similar of the profile 5
Cabría decir algo similar del perfil 5, con la salvedad
with the salvage of a small minimum, almost superficial, in the station 5-3
de un pequeño mínimo, casi superficial, en la estación 5-3 -
that is not worth major comentatio put that its justification can
que no merece mayor comentario puesto que su justificación
be lithologic or of error of reading in the corresponding
puede ser litológica o de error de lectura en el canal co-
Chanal.
rrespondiente.

Un tanto más complicado es el perfil 6 que aparece dividido en dos bloques conductores por efecto de un umbral resistivo entre los puntos 6-4 y 6-5. Al mínimo del inicio del perfil le consideramos efecto de la falla pudiendo observarse como se manifiesta preferentemente en el rango de 39,5 - 130 Hz. Por el contrario, suponemos un origen litológico para la anomalía existente entre los puntos 6-5 a 6-8. Su valor absoluto no baja de 100 ohm.m (recordemos la arbitrariedad de la escala empleada) y puede deberse a la presencia de una zona preferentemente arcillosa en un rango de profundidades entre 400 y 700 metros.

To the seperation of the zone of the fault dissappear its effect
Al alejarnos de la zona de falla desaparece su efecto -
characteristic and the profile samples an almost uniform aspect;
característico y los perfiles muestran un aspecto casi unifor-
within the model of three mantles that correspond to the
me; dentro del modelo de tres capas que corresponderán al mo-
model H in curves of SEV. The profile 7 is a good ejemple.
delo H en curvas de SEV. El perfil 7 es un buen ejemplo

Completely different is the model that appears in the
Completamente diferente es el modelo que aparece en el
profile 8 where they manifest two minimums of different explication.
perfil 8 donde se manifiestan dos mínimos de diferente expli-
While those of the points have to think in an
cación. Mientras el de los puntos 8.4 y 8.5 hace pensar en un
origin in relation with the faults, it is not admissible to say the same of
origen en relación con la falla, no cabe decir lo mismo de la
the central zone in the point 8.8, that we consider erroneous. If
zona centrada en el punto 8.9, que consideramos erroneo. Si -
an anomaly really exists downhill to think that it manifests
realmente existiera una anomalía cuesta pensar que se mani-
in only one point of intense form and not in the adjacent.
fieste en un solo punto de forma intensa y no en los adyacentes

De cualquier forma existe una cierta continuación de esta posible zona conductora en el siguiente perfil, entre las estaciones 7-8 y 9-10. Su justificación habrá que buscarla en la presencia de materiales arcillosos porque esta posibilidad es más coherente que pensar en una surgencia de fluidos calientes que produzcan una saturación en los materiales dentro del rango de profundidades en que se manifiesta la anomalía. El efecto de la falla aparece aquí entre las estaciones 9-3 y 9-4. Puede observarse, en el punto 9-1, una cierta alteración en el granito. Efectivamente, a partir de superficie existe una bajada de resistividad hasta un rango del orden de 150 metros con un incremento muy acusado al aumentar la penetración del sistema.

El perfil 11 comprende algunos puntos del 10 del 12 y del 13, su dirección es más o menos paralela a la falla y sus rasgos característicos responden al modelo de tras capas de tipo H.

Between the points exists a conductor anomaly
Entre los puntos 13-5 y 11-8 existe una anomalía conduc-
in related with the definition by electric (SEV) methods
tora en estecha relación con la definida por métodos eléctri-
and thermométric by that it ought to consider it as
cos (SEV) y termométricos por lo que cabe considerarla como
of geothermal origin
de origen geotérmico.

Within the profile 12, apart from the effect of the fault, in
Dentro del perfil 12, aparte del efecto de la falla, en
the point 12.2 appears a superposition of zone conductor that
el punto 12.2 aparece una superposición de zona, conductora
extends until the 12-6. We suppose it is within the
que se extiende hasta el 12-6. La suponemos dentro de la ano-
geothermal anomaly next to
malía geotérmica próxima a La Garriga.

Practically anomaly in all its amplitude is the profile
Practicamente anomalo en toda su amplitud es el perfil
13 that is situated within the anomaly of
13 que se sitúa dentro de la anomalía de La Garriga.

A la vista de esta seudosección parece que la citada anomalía tiene una conexión en profundidad tanto a través del -- área de fractura como a lo largo de los puntos 13.5, 13.6, -13.7. Cabe señalar que, mientras la termometría y la prospección mediante SEV, señalaban una anomalía homogenea y amplia, aquí aparece más compartimentada por efecto del carácter puntual de las medidas.

We turn to appear; in the profile 14 stake 14.4; the possible
Vuelve a aparecer; en el perfil 14 estaca 14.4; la posi
zone of connection in depth of the anomaly conducto
ble zona de conexión en profundidad de la anomalía conductora
that here it manifests in practically all the profile to
que aquí se manifiesta en prácticamente todo el perfil a pro-
depths of → To split of the point 14.6 it appears to insinuate
fundidades de 300-450 m. A partir del punto 14.6 parece insi-
a blunt rise of the basement resistivity
nuarse una subida brusca del basemento resistivo.

In the proximity of Samalús exists a prolongation of
En las cercanías de Samalús existe una prolongación de
the above mentioned anomaly of La Garriga, that it manifests in the profile
la citada anomalía de La Garriga, que se manifiesta en el per
15 between the points → without that exists other features
fil 15 entre los puntos 15.2 y 15.3 sin que existan otros ras
of saline interest the confirmation of the clasic model of three mantels
gos de interés salvo la confirmación del modelo clásico de -
tres capas.

La continuación hacia el NE de la exploración puede observarse en el perfil 16 que presenta una anomalía en el punto 16.6 de difícil justificación.

Por último existe el perfil 17 que no presenta ninguna característica digna de mención.

6.2.3.- Modelos de Strangway

Basically they contribute the same information that the pseudo-
Básicamente aportan la misma información que las seudose
sections already comment.
cciones ya comentadas.

The fundamental difference supported in that this type of
La diferencia fundamental estriba en que este tipo de
representation is most exhaustive that the pseudo
representación es ligeramente más exahustiva que las seudosec
sections put that while those elaborate for a number
ciones puesto que mientras aquellas se elaboran para un núme-
restricting of frequencies, in the models of Strangway -
ro restringido de frecuencias, en los modelos de Strangway -
they have in count all the canals
se tienen en cuenta todos los canales.

The figures 13 to 30 demonstrate the results corresponding to
Las figuras 13 a 30 muestran los resultados correspon-
the N-S direction of the electric dipole. The discrepancy
dientes a la dirección N-S del dipolo eléctrico. La discrepan
with the perpendicular direction is important in many
cia con la dirección perpendicular es importante en muchos -
profiles which indicate that the anisotropic is important.
perfiles lo cual indica que la anisotropía es importante.

Conviene reseñar otra característica de interés como es el hecho de que estos modelos no tienen un sistema de referencia común por lo que la comparación entre ellos ha de hacerse con muchas reservas, al contrario de lo que puede hacerse para las seudosecciones.

Para no hacer exahustiva la descripción de los diversos perfiles vamos a emitir otros comentarios porque consideramos que es más interesante pasar a la variación lateral de resistividades para diversos rangos de profundidad que comentamos en el apartado siguiente.

Maps of isoresistivities
6.2.4.- Mapas de isorresistividades

In homogeneous conditions to a determining corresponding
En condiciones homogeneas a una determinada frecuencia
frequency a feature of definite depth by the formula
correspondería un rango de profundidades definido por la fór-
of the skin in function of superficial resistivity
mula del skin en función de la resistividad superficial.

We are really seperating of this theoretic situation
Realmente estamos alejados de esta situación teórica -
by that we can only take as criteria a depth
por lo que solo podemos tomar como criterio una profundidad
of increasing investigation according to the frequencies
de investigación creciente según las frecuencias 3800, 490, 39,5 y 8,3 Hz.

The plane no 3 corresponds to 3800 Hz presents a series
El plano nº 3 correspondiente a 3800 Hz presenta una se
of conductor anomalies associated fundamentally to the
rie de anomalías conductoras asociadas fundamentalmente a la
sketch of the fault save a more amplified in the area of
traza de la falla salvo una más amplia en el área de Llerona.
Of whichever form this plan corresponds to a small depth
De cualquier forma este plano corresponde a una pequeña profun
that
didad que no sobrepasará el centenar de metros por lo que esta segunda anomalía no debe tenerse en cuenta desde el punto de vista geotérmico.

Para la frecuencia de 490 Hz vuelve a señalarse la zona conductora, a lo largo de la falla entre Santa Eulalia de Ronsana y Samalús así como en el área de Sentmenat.

De manera análoga se manifiesta la anomalía conductora de Llerona. La profundidad a que cabe atribuir este mapa es del orden de 160-200 m.

Cuando la penetración aumenta hasta un orden de 600-700 metros, que es la profundidad que viene a corresponder a 39,5 Hz, las zonas anómalas aparecen mal localizadas. Se aprecia claramente la anomalía de La Garriga y la continuación hacia Sta. Eulalia de la posible traza de la falla a esa profundidad. Hacia Caldas de Montbuí se observa un ensanchamiento del área anómala tendiendo a corresponder con la antigua anomalía conocida en la zona por los estudios previos. La ampliación del área conductora hacia el SE de Sta. Eulalia cabe justificarla como debida a la existencia de agua caliente que asociada a la falla, sature los materiales a esa profundidad.

Al considerar la frecuencia de 8,3 Hz el orden de profundidad investigada alcanza los 1600-1800 m. Se manifiesta una zona anómala con claridad en la zona de La Garriga con posible continuación hacia Samalús. Persiste, por otra parte, un mínimo de resistividad al NE de Santa Eulalia de Ronsana.

De una manera análoga se aprecia un mínimo importante en Caldes de Montbuí con continuación, a lo largo de la falla, hacia el NE. Su relación con el geotermismo del área parece indudable. Una última zona conductora es la existente entre los puntos 6-8 y 8-9 respecto a la cual no aventuramos ninguna hipótesis que justifique su existencia.

Como síntesis al comentario de todos estos planos cabe señalar que los umbrales de anomalía, tal vez habrían de haberse definido para cada litología, dentro de cada frecuencia. Esto, teóricamente más correcto, puede no ser realizable en la práctica por lo cual es preferible el tratamiento como litología uniforme aunque esto lleve asociada una pérdida de precisión que se traduce en el señalamiento de amplias zonas con resistividad inferior a la media. Por este motivo solo consideramos como anomalías aquellas areas con resistividad inferior a la media menos una desviación standard.

7.- CONCLUSIONES

Upon judging the results obtained had to have
Al juzgar los resultados obtenidos han de tenerse en -
encountered two factors that the conditional in great manner
cuenta dos factores que los condicionan en gran manera.

By a part is the main occasion in that board a
Por una parte es la primera ocasión en que se aborda un
study of this type in Spain. The equipment employed so as
estudio de este tipo en España. El equipo empleado así como
the treatment of the data has suffered modifications to it
el tratamiento de los datos ha sufrido modificaciones a lo -
large of the work with the object of optimizing the response in
largo del trabajo con el objeto de optimizar la respuesta en
each situation although without controls defined in those that
cada situación aunque sin controles definidos en los que con-
contrast the results that were obtained.
trastar los resultados que se iban obteniendo.

In second place have influence, and much, the geologic
En segundo lugar han influido, y mucho, las caracterís-
characteristics of the area of work. We have worked about
ticas geológicas del área de trabajo. Hemos trabajado sobre
a model with accusions contrasting laterals of resistivity,
un modelo con acusados contrastes laterales de resistividad,
especially the western fault of the Vallés, that the readings
especialmente la falla occidental del Vallés, que condicionan
coincide and upset the interpretation.
las lecturas y perturban la interpretación.

All this has come aggravated by a third factor: the
Todo esto ha venido agravado por un tercer factor: la
presence of an elevated industrial noise. Its immediate rendering
presencia de un elevado ruido industrial. Su traducción in-
consists in the repetition of diverse points
mediata consistió en la repetición de diversos puntos.

In synthesis and having in count the anterior factors
En síntesis y teniendo en cuenta los anteriores factores
the results obtained are coherent with the previous knowledge
los resultados obtenidos son coherentes con el conocimiento -
of the area and we are able to summarize in the following
previo del área y se pueden resumir en los siguientes puntos.
points

The data of the magnetotelúric soundings permit us to elaborate
- Los datos de los sondeos magnetotelúricos permiten elaborar
the map nº 7 that is a primary estimation of the ~~density~~ Thickness
el mapa nº 7 que es una primera estimación de los espesores
of sediments in the western border of the depression.
de sedimentos en el borde occidental de la depresión.

Mediating the diverse treatment gives the Audio-MT
- Mediante los diversos tratamientos dados a los sondeos Audio-
soundings studied the distribution of resistivities in three
MT se ha estudiado la distribución de resistividades, en tres
dimensions, within all the zone of the study
dimensiones, dentro de toda la zona de estudio.

- Se ha observado una evolución en profundidad de las diferentes anomalías, especialmente las ya conocidas, en el sentido de que su presencia es tanto más visible cuanto mayor es la profundidad; lo cuál confirma un posible origen geotérmico.

  Having observed an evolution in depth of the different anomalies, especially those already known, in the feeling that its presence is visible enough when it is deep; as it confirms a possible geothermal origin

- Como dato nuevo aparece en casi todos los casos una zona conductora, cercana a la falla, a la que cabe suponer un doble origen: De una parte la posible presencia de agua caliente asociada a la zona fracturada y por otra parte la falsa anomalía que en los métodos eléctricos aparece asociada al contacto con medios muy resistivos.

  As new data appears in almost all the cases a zone conducted next to the fault, suppose that it contains a double origin: Of a part the possible presence of hot water associated by the zone fractured and by another part the false anomaly that in the electric methods appears associated to the contact with very resistive mediums.

- El presente trabajo ha puesto de manifiesto una nueva zona anómala que, a pesar de su pequeña amplitud, es persistente en casi todos los tratamientos. Esta zona se halla en las cercanías de Santa Eulalia de Ronsana y siempre muy próxima a la falla.

  The present work has enabled the manifesting of a new zone anomaly that to regret of its small amplitude is persistent in almost all the treatments. This zone found in the surroundings of and always very close to the fault.

Con esta fase consideramos que se ha cubierto el objetivo que se planteó al programar el trabajo puesto que se ha cubierto un rango de profundidades mayor que el de los trabajos previos, señalándose las anomalías ya conocidas aparte de algunos datos complementarios de interés. Todo ello dentro de las especiales características de un método de campo natural como el empleado.

With this phase we consider that has covered the objective that states to the program the work put that has covered a range of major depths that of the previous jobs, signaling the anomalies already known apart from other data complementary of interest. All those within the special characteristics of a method of natural field as the employed.

Madrid, Noviembre de 1979.

MINISTERIO DE INDUSTRIA Y ENERGIA

INSTITUTO GEOLOGICO Y MINERO DE ESPAÑA

STUDY OF INTERCEDING "DIPOLE MAPPING"
ESTUDIO MEDIANTE "DIPOLE MAPPING" DE LAS
OF THE GEOTHERMAL ANOMALIES OF SPRINGS OF
ANOMALIAS GEOTERMICAS DE CALDES DE MONTBUI
MONTBUI AND THE GARRIGA
Y LA GARRIGA.

GEOPHYSICAL STUDY OF INTERCEDING DIPOLES OF THE GEOTHERMAL
ESTUDIO GEOFISICO MEDIANTE DIPOLOS DE LAS ANOMALIAS GEOTER-
ANOMALIES OF SPRINGS OF MONTBUI AND THE GARRIGA
MICAS DE CALDES DE MONTBUI Y LA GARRIGA.

- -

INTRODUCTION
1.- INTRODUCCION

Within the geothermal reserve of the Valles has been
Dentro de la reserva geotérmica del Vallés se
come realizing by the IGME a series of preliminary studies.
han venido realizando por el IGME una serie de estudios pre-
Following a methologic more or less conventional
liminares. Siguiendo una metodología más o menos convencio-
effected a first hydrochemical study and isotopic
nal se efectuó un primer estudio hidroquímico e isotópico
and simultaneously a geophisical prospection by restivitiles, in its
y simultáneamente una prospección geofísica por resistivida
variation of Electronic Vertical Soundings
des, en su variante de Sondeos Eléctricos Verticales (SEV)

As results of these works are defined
Como resultado de estos trabajos se definieron
two areas of anomalies in stretch relation with the thermal
dos áreas anómalas en estrecha relación con las manifestacio-
manifestations of the Springs of Montbui and La Garriga
nes termales de Caldes de Montbuí y La Garriga.

Afterwards it effects a mesh of sounds
Posteriormente se efectuó una malla de sondeos
for measurement of temperatures of manner that in the base of the
para medida de temperaturas de forma que en base a los re-
results obtained it is able to construct the map of geothermal
sultados obtenidos se pudo construir el mapa de gradiente -
gradiation and that of calorific fluids. This second phase comes, to
geotérmico y el de flujo calorífico. Esta segunda fase vol-
put in evidence the existence of the same anomalies already
vió a poner en evidencia la existencia de las mismas anoma-
defined in the previous phase.
lías ya definidas en la fase previa.

calorific = thermal

It is then set forth, the convenience of the
Se planteó entonces, la conveniencia del em-
employment of some other method that was capeable of contributing new
pleo de algún otro método que fuera capaz de aportar nueva
information or when less ratify it, until then, - well known.
información o cuando menos ratificar lo, hasta entonces, -
coincide The method of the "dipole-mapping" so as the magnetoteluric
conocido. El método del "dipole-mapping" así como el magne-
in some of its variations are those that offer
totelúrico en alguna de sus variantes son las que ofrecen
greater possibilities by it that propose its employment for
mayores posibilidades por lo que se propuso su empleo para
an exhaustive acknowledgement of this this geothermal Reserve of the State
un reconocimiento exahustivo de esta Reserva geotérmica del

Estado.

In the pages that follow we give count of the characteristics
En las páginas que siguen damos cuenta de las ca-
and fundamentals of the method of the "dipole-mapping"
racterísticas y fundamentos del método del "dipole-mapping"
To continue we comment its application to the acknowledgement of
A continuación comentaremos su aplicación al reconocimiento
the anomaly of Springs of Montbui evaluating the result-
de la anomalía de Caldes de Montbuí valorando los resulta--
two obtaining and marking the adequate conclusions to having
dos obtenidos y señalando las conclusiones adecuadas al te-
in calculating all the coinciding data.
ner en cuenta todos los datos conocidos.

EQUIPMENT UTILIZED

3.- EQUIPO UTILIZADO

The execution of a prospection by the system
La ejecución de una prospección por el sistema
of dipolar mapping requires the employment of conventional electric
de mapeo dipolar requiere el empleo de un equipo eléctri-
equipment, in principal. It is good when we pretends,
co convencional, en principio. Ahora bien cuando se preten-
as in our case, to reach certain depth of investigation
de, como en nuestro caso, alcanzar cierta profundidad de -
is convenient in the employment of an weighted equipment
investigación es conveniente el empleo de un equipo pesado
as presented by two fundamental characteristics:
lo cual presenta dos características fundamentales:

Necessity of a spring of potent feeding for producing
a) Necesidad de una fuente de alimentación potente para
an electric country checking in an amplified zone.
producir un campo eléctrico chequeable en una amplia -
This demands excellent contacts between electrodes of
zona. Esto exige contactos excelentes entre electrodos
current and terrain
de corriente y terreno.

Precision in the lectures that, when they effect in
b) Precisión en las lecturas que, cuando se efectúan en
separated points of the bipole emittor, they are able to be very weak.
puntos alejados del bipolo emisor, pueden ser muy dé-
biles.

The equipment employed by us in this prospection has
El equipo empleado por nosotros en esta prospec-
been the following:
ción ha sido el siguiente:

GENERATOR

3.1.- GENERADOR

HONDA model ES-3500 with the following characteristics:
HONDA modelo ES-3500 con las siguientes caracterís
ticas:

- Motor HONDA de cuatro tiempos.
- Potencia nominal 2,8 KVA (C.A.)
- Potencia máxima 3,5 KVA (C.A.)
- Tensión de salida variable entre 115-230 V
- Corriente alterna de 60Hz.
- Rectificador de corriente.

- Estabilizador a una tensión previamente seleccionada.
- Monitores de control de tensión de salida de bornes y tensión del estabilizador.
- Cables con doble aislamiento y resistencia eléctrica muy pequeña.
- Electrodos de cobre formados por placas enterradas y regadas con disolución de SO_4 Cu.

CONTROL UNIT

3.2.- UNIDAD DE CONTROL.

Marca GEOTRON modelo GEO-400 con las características siguientes.

- Monitorización del voltaje del generador.
- Monitorización del voltaje entre electrodos A y B
- Regulación continua del voltaje en c.c. entre 0, y 800 V. Esto permite la posibilidad de trabajar a intensidad constante para cualquier separación de electrodos A, B.
- Monitorización de la corriente de trabajo en cinco márgenes 30 mA, 100 mA, 300 mA 1 Amp. y 3 - Amp. a fondo de escala.
- Medida independiente de resistencia de contacto de los electrodos A y B.
- Doble circuito de protección que desconecta la tensión entre electrodos en caso de sobrecarga.
- Posibilidad de empleo de las líneas de emisión como líneas de comunicación.
- Permite la utilización de potencias de pico de hasta 5 KVA.

3.3. REGISTRADOR

De HOUSTON INSTRUMENT, modelo OmniScribe serie - 5000. Sus características son las siguientes:

- Entrada flotante ente ± 200 V (cc).
- Resistencia de entrada entre 1 y 8 Mohm.
- Cero variable en toda la escala.
- Tiempo de respuesta ½ segundo.
- Sobretensión de 2% sobre cada margen a fondo de escala.
- Linealidad ± 0,2% a fondo de escala.
- Repetibilidad ± 0,1% del fondo de escala.
- Exactitud total ± 0,3% del fondo de escala.
- Alimentación por CA 115/230 V ± 10% y frecuencia entre 50-60 Hz.
- Potenciómetro opcional para eliminación de tensiones parásitas.

3.4. MILIVOLTIMETRO.

Es un equipo de circuitos integrados marca INTERSIL con lectura digital. La amplitud de su escala vería entre - 0-999 mV con sensibilidad de 0'1 mV. Dispone de circuito - potenciómetro para puesta a cero.

Como elementos accesorios se han empleado conmutadores de cuchillas para la inversión del sentido de la corriente así como milivoltímetros digitales para conocimiento de la magnitud de los autopotenciales en diversas zonas.

REALIZED WORK

4.- TRABAJO REALIZADO.

The ideal situation for the execution of an
La situación ideal para la ejecución de una
in depth prospection by the system of "dipole-mapping"
prospección en profundidad por el sistema del "dipole -mapping".
was there that permitted the establishment of bipoles of large
sería aquella que permitiera el establecimiento de bipolos de
dimensions and the employment of intensities of elevated currents.
grandes dimensiones y el empleo de intensidades de corriente
From this form we are able to map large extensions of
elevadas. De esta forma se podrían mapear grandes extensiones
terrain without the necessity of relating between if the results
de terreno sin necesidad de relacionar entre sí los resulta-
obtained This labor is able to generate notable errors.
dos obtenidos. Esta labor puede generar errores notables.

To generous of the previous phases of the geothermal
A lo largo de las fases previas de investiga-
investigation of the Valles they were able of diverse difficult inherent
ción geotérmica del Vallés se pusieron de manifiesto diver-
manifestations to the high density of population and
sas dificultades inherentes a la alta densidad de población
civil construction existences in the zone. In our case the
y obras civiles existentes en la zona. En nuestro caso el -
employment of great intensities have not been feasable for elemental
empleo de intensidades grandes no ha sido factible por ele-
reasons of ourgence and this has conditioned a clear
mentales razones de seguridad y esto ha condicionado de ma-
manner of all work
nera clara todo el trabajo.

Effectively to be limited the intensity of the
Efectivamente, al estar limitada la intensidad
emittor, and to think of the high sensibility of the receptor,
del emisor, y a pesar de la alta sensibilidad del receptor,
we made covered reductions to measure within an area of smaller
nos hemos visto reducidos a medir dentro de un área de menor
extention of that we have possessed desiring(3)
extensión de la que nosotros hubiéramos deseado.

The amplitude of the bipoles transmitted established
La amplitud de los bipolos emisores se estable-
having in count the lithologic characteristics of each
ció teniendo en cuenta las características litológicas de -
zone thus as the possible perturbed factors, especially
cada zona así como los posibles factores perturbadores, espe-
those of industrial type Its direction again having
cialmente los de tipo industrial. Su dirección también ha -
conditional by these factors and by the abundance of
venido condicionada por estos factores y por la abundancia
constructions of all all types.
de construcciones de todo tipo.

In the establishment of the transmitter puts special
En el establecimiento del emisor se puso espe-
care handeled of achieving good electrical contacts
cial cuidado tratando de conseguir buenos contactos eléctri-
and to prevent escapes in the line. Respect to the primer point
cos y evitar fugas en la línea. Respecto al primer punto se

employ as electrodes plates of copper burried and
emplearon como electrodos placas de cobre enterradas y re-
covered with disolution of SO_4Cu
gadas con disolución de SO_4 Cu.

In each point of measurement two dipole receptors
En cada punto de medida se establecieron dos
were established in directions sensibly perpendicular between indeed
dipolos receptores en direcciones sensiblemente perpendi-
In these dipoles the conventional impolarizable
culares entre sí. En estos dipolos se emplearon electrodos
electrode were employed separated by 50 meters.
impolarizables convencionales separados a 50 metros.

La distribución de las estaciones de lectura se hizo de forma regular tratando de cubrir adecuadamente el entorno de cada bipolo.

Para cada posición del emisor se procuró trabajar a intensidad constante, siempre que se pudo.

El elemento más delicado de toda la operación es el milivoltímetro que ha de poseer una sensibilidad alta, orden de 0'1 mV, junto con buenas condiciones de repetibilidad. Dependiendo de la magnitud y condiciones de la lectura hemos empleado bien el registrador o el milivoltímetro digital.

Una vez obtenidos todos los datos de campo se procedió a su tratamiento matemático para obtener las resistividades aparentes. Para ello empleamos la expresión:

$$\rho_a = 2\pi R_1^2 \left[1 + \left(\frac{R_1}{R_2}\right)^4 - 2\left(\frac{R_1}{R_2}\right)^2 \cos D \right]^{-\frac{1}{2}} \cdot \frac{\sqrt{\Delta V_1^2 + \Delta V_2^2}}{I}$$

siendo los valores obtenidos los que tabulamos a continuación:

PRESENTATION OF THE RESULTS

5.- PRESENTACION DE LOS RESULTADOS.

The usual form is interceding maps of isoresistivity that they obtain for each position of the dipole transmitter

La forma usual es mediante mapas de isorresistividad que se obtienen para cada posición del dipolo emisor.

The connection of values between adjacent dipoles is a problem of difficult solution putting that the parameter that drives is the apparent resistivity and not the real resistivity. In consequence its value comes very influentially by the corresponding constant geometry. If to this we unite the existences of inhomogenities, in the middle to studying the complexity of the problem we can increase until it limits irresolubilities

El enlace de valores entre dipolos adyacentes es un problema de difícil solución, puesto que el parámetro que manejamos es la resistividad aparente y no la resistividad real. En consecuencia su valor viene muy influenciado por la constante geométrica correspondiente. Si a esto unimos la existencia de inhomogeneidades, en el medio a estudiar la complejidad del problema puede aumentar hasta límites irresolubles.

The general model that are included in the seperation of theoretic models arrive its information more clearly for good zones seperate from the transmitter. By the operative commentators limitations have not obtained, in our case, information in areas situated so far of currents of electrodes

Los modelos generales que se incluyen en el apartado de modelos teóricos aportan su información más clara para zonas bastante alejadas del emisor. Por las limitaciones operativas comentadas no hemos obtenido, en nuestro caso, información en áreas situadas tan lejos de los electrodos de corriente.

As always we have signaled, the values of apparent resistivity are able to present very accusing contrasts between adjacent dipoles. For this reason the intervals elected for the confection of the curves of isoresistivity, are variables of some to other dipoles

Como ya hemos señalado, los valores de resistividad aparente pueden presentar contrastes muy acusados entre dipolos adyacentes. Por esta razón los intervalos elegidos para la confección de las curvas de isorresistividad, son variables de unos a otros dipolos.

We must say that we move with our data within a half open(?) similar to that having been compared our results with this model and to treat of offering adequate justifications to the discrepancies with the real dates, always within relative variations of resistivity and not of absolute values

Puesto que nos moveremos con nuestros datos dentro de un entorno similar lo que haremos será comparar nuestros resultados con este modelo y tratar de ofrecer justificacio nes adecuadas a las discrepancias con los datos reales, siem pre dentro de variaciones relativas de resistividad y no de valores absolutos.

ZONE OF SPRINGS

6.1.- ZONA DE CALDES.

device, apparatus

Transmitter dipole The dipole transmitter was sensibly situated perpendicular to the western fault of the Valles in the proximity of Sentmenat, and with a total length of 2 Km. The middle zone is represented in Fig. 9, with 20 stations.

Dispositivo 1.- El dipolo emisor se situó sensiblemente perpendicular a la falla occidental del Vallés en las cercanías de Sentmenat, y con una longitud total de 2 Km. La zona medida es la representada en la fig. 9, con 20 estaciones.

The resistivity curves clearly follow the pattern of the model of fig. 7 especially in the northern border

Las curvas de resistividad se acercan claramente al modelo de la figura 7, especialmente en su borde N.

By the southern zone one estimates a perturbed conductor makes Sentemat probably motivated by the predominance of clay materials in front of the greater abundance of conglomerates in the rest of the area

Por la zona sur se aprecia una perturbación conductora hacia Sentmenat motivada probablemente por el predominio de materiales arcillosos frente a la mayor abundancia de conglomerados en el resto del área.

Again one estimates a strong gradient of resistivity in the vicinity of the fault as corresponding to the acknowledged contrast between granite and clay - arcose.

También se aprecia un fuerte gradiente de resistividad en las cercanías de la falla como corresponde al acusado contraste entre granito y arcillas-arcosas.

Its objective is the study of the anomaly
Dispositivo 2.- Su objetivo era el estudio de la anomalía
South of the Caldes of Montbui and for it they have established
del Sur de Caldes de Montbui y para ello se establecieron
35 lecture stations in around to the dipole transmitter of Fig. 10.
35 estaciones de lectura en torno al dipolo emisor de la figura 10.

Respecto al modelo teórico, se aprecia una perturbación clara centrada sobre la anomalía geotérmica ya conocida de anteriores trabajos. Esta zona se manifiesta tanto en sus menores valores absolutos como en la mayor amplitud de la zona de resistividad menor de 1000 ohm.m.

A la vista de este gráfico cabe afirmar la buena respuesta del método frente a anomalías ya conocidas, cuando el dispositivo emisor se sitúa en las cercanías de la zona anómala.

Dispositivo 3.- Sus resultados, que se indican en la figura 11, son sustancialmente diferentes de los anteriores en su forma general.

El efecto más acusado es el debido a la falla puesto que en sus cercanías existe un gradiente de resistividad muy fuerte. La disminución en la resistividad aparente en las proximidades del electrodo A es en efecto debido al citado electrodo, que como muestra el modelo (fig. 8), hace aparecer una zona conductora asociada a cada electrodo de corriente.

Otro rasgo de interés digno de mención es lo que parece ser una prolongación de la zona conductora, asociada al electrodo B, hacia la anomalía del dispositivo 2 y ya comentada.

Aparte de esto puede observarse una cierta curvatura de las líneas de isorresistividad en la zona de las estaciones 57, 74 y 88 en buena correspondencia con el cono torrencial existente en el área.

Dispositivo 4.-

La zona de mayor interés dentro de todo el área a cubrir es la situada al sur del electrodo B. Debido a la abundancia de construcciones en esa zona, y al carácter privado de muchas de ellas (fig. 12)

Se puede apreciar también aquí, de forma clara, el efecto de la falla por el fuerte gradiente de resistividad asociado a ella.

Hacia el sur se inicia una zona de mínimo de resistividad respecto a cuya influencia carecemos de datos por lo anteriormente apuntado. Cabe considerar, no obstante, que su causa sea litológica - mayor predominio de arcillas - antes que de otro tipo.

6.2. ZONA DE LA GARRIGA

Dispositivo 1. De todos los anteriormente comentados se diferencia en la orientación del dipolo emisor respecto a la falla (fig. 13)

El aspecto general de todas las curvas, no muestra ningún rasgo de interés, desde el punto de vista de señalar -

anomalías geotérmicas. Todas las isolíneas son sensiblemente paralelas a la previsible traza de la falla y se observa un crecimiento general de la resistividad aparente hacia dentro del macizo granítico.

Dispositivo 2.-

La disposición del dipolo emisor es prácticamente paralela a la del caso anterior y más hacia dentro de la depresión como puede verse en el plano nº 14.

En la zona que queda al NW. del emisor se continúa el aspecto general de las curvas del dispositivo anterior: sensible paralelismo con la dirección del emisor.

Como digna mención destaca una amplia zona conductora inmediatamente al SE. de La Ametlla . La proximidad a la anomalía de La Garriga sugiere que su justificación sea producida por el mismo efecto, es decir fenómenos geotérmicos. No obstante esta hipótesis se ve limitada por un crecimiento rápido de las resistividades aparentes entre las estaciones 52-57 y 58-59.

Dispositivo 3.- Centrado prácticamente sobre la anomalía geotérmica de La Garriga, presenta características comunes a los diversos modelos comentados.

Por una parte las líneas isorresistivas se distribuyen paralelamente a la falla y con un gradiente importante como corresponde al paso de detrítico a granito.

Hacia dentro de la depresión el modelo es claramente conductor con apertura importante de la línea de 1000 ohm.m en la zona de la anomalía geotérmica conocida.

Sus resultados vuelven a confirmar la utilidad del método dentro de un entorno reducido. Lo representado en la figura 15 es un ejemplo claro de la respuesta que cabe esperar frente a contrastes acusados de resistividad y frente a anomalías conductoras, en función de la posición relativa del dispositivo emisor.

Dispositivo 4.-

Puede verse en la figura 16 como sus resultados son coherentes con el conocimiento actual de la zona ocupada por las lecturas.

Efectivamente, dentro de un buen encaje con el modelo teórico, se observa un fuerte gradiente hacia los materiales resistivos y una amplitud relativa considerable de los mínimos de resistividad asociados con los electrodos de emisión.

El mínimo del electrodo A comprende una zona extensa en clara conexión con la anomalía de La Garriga a pesar de que sus valores absolutos de resistividad aparente no son muy bajos.

Respecto al mínimo de Samalús hay que señalar que, pese a su proximidad a la falla con su influencia resistiva, aparece bien definido y en consecuencia hemos de pensar - en la existencia de una zona anómala de baja resistividad asociada a él.

7.- CONCLUSIONES.

The dipole mapping method has demonstrated its utility
- El método del mapeo por dipolos ha demostrado su utilidad
in geothermal exploration of different and diverse areas
en la prospección geotérmica de diferentes áreas en diver
of the earth
sas partes del mundo.

Its application to the anomalies of Caldes (Warm Springs) of Montbui and the
- Su aplicación a las anomalías de Caldes de Montbuí y La
Garriga has come conditional for the abundance of structures
Garriga ha venido condicionada por la abundancia de cons-
of all types which exist in the zone of study.
trucciones de todo tipo que existen en la zona de estudio.

For reasons of certainty we have viewed limited in the
- Por razones de seguridad nos hemos visto limitados en el
employment of the energy of the dipole transmitter and in consequence
empleo de la energía del dipolo emisor y en consecuencia,
the extension of the zone studied for each one of
en la extensión de la zona estudiada para cada uno de -
them
ellos.

The results obtained are consistent with the knowledge
- Los resultados obtenidos son concordantes con el conoci-
that it has of the Reserva Estatal and with the geologic
miento que se tenía de la Reserva Estatal y con la situa-
situation in each area measured
ción geológica en cada área medida.

It has confirmed, basically the existence of the
- Se confirma, fundamentalmente, la existencia de las ano-
geothermal anomalies of Caldes and the Garriga, as well as the
malías geotérmicas de Caldes y La Garriga, así como la -
extention of this finish toward Samalus.
prolongación de esta última hacia Samalús.

We are able to affirm that this Project has covered the proposed
- Podemos afirmar que este Proyecto ha cubierto los objeti-
objectives and in consequence, contributed a complementary knowledge
vos propuestos y, en consecuencia, aporta un conocimiento
of interest to the geothermal investigation of the Vallés
complementario de interés a la investigación geotérmica de
El Vallés.

Madrid, Noviembre 1979

C.G.S.

Howard - from Waring. 1965

PORTUGAL

Portugal occupies an area about 300 miles long, north-outh, and 100 miles wide, east-west, on the west side of he Iberian Peninsula. The country is traversed by nountain ranges that trend east-west and are continua-ions of ranges in Spain. Most streams flow westward o the Atlantic. The Minho River forms part of the orthern boundary; the Guadiana River forms part of he southeastern boundary. The greater part of Portu-al is underlain by rocks of Archean and Paleozoic ages, ut by eruptive rocks of later dates, like the syenite lac-olith of Serra de Monchique in the south. In the south lso are extensive areas of Lower Carboniferous sand-tone and conglomerate, with coal beds. Mesozoic deposits, chiefly of Jurassic age and less extensive areas of Cretaceous rocks, are present in lower areas. The plain of the Tagus River and other large areas near the coast are covered by Tertiary deposits. Great eruptions of basalt and tuff in early Tertiary time are covered in part by marine deposits of Oligocene and Miocene age. The mountains of northern Portugal are mainly of plutonic rocks flanked by Paleozoic sedimentary strata. Thermal springs are not common, though 34 localities are recorded, as shown on figure 40. Most of them have been developed as bathing resorts.

Information on the various springs in Portugal is presented in the table below.

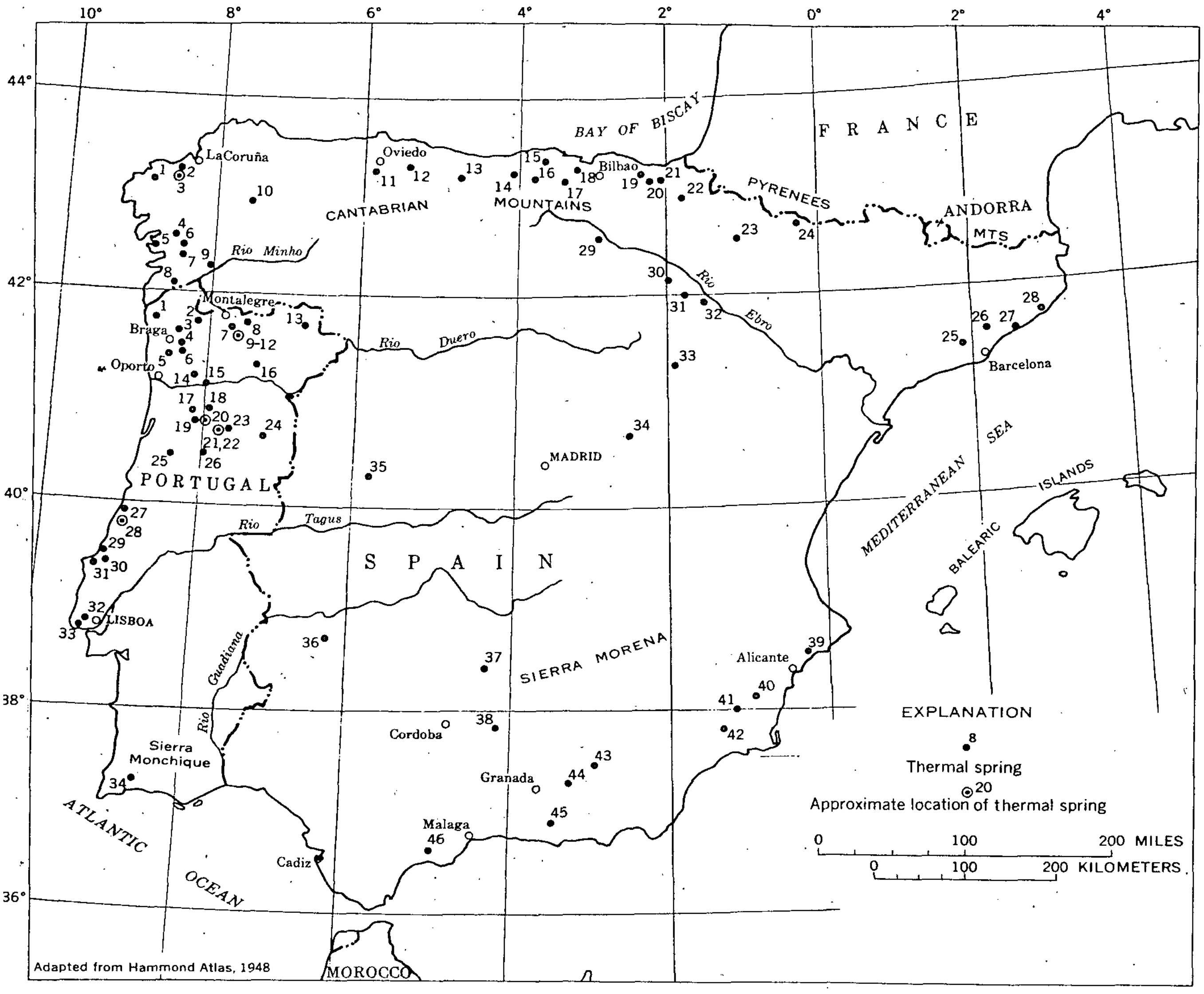


FIGURE 40.—Portugal and Spain showing location of thermal springs. Portugal from refs. 2268 and 2272; Spain chiefly from ref. 2346.

Thermal springs and wells in Rumania—Continued

No. on fig. 41	Number or location	Temperature of water (°C)	Flow (hectoliters per day)	Total dissolved solids (ppm)	Principal chemical constituents	Remarks and references
8	Tusnad (Ilona)	21; 22.5		5,254		Ref. 2330.
9	Caciulata					Mineralized. Ref. 2308.
10	Vizakna	28.7–45				Saline, iodine.
11	Herculesbad (Mehadia):					
	Elizabeth					
	Hygea					
	Hercules	46	38,400	3,440	Na, Ca, Cl; gas, 40 percent N_2.	Radioactive. Water temperature, 25°–62.5°C. Ancient "Thermae Herculis ad aquas." Refs. 2309, 2323, 2325, 2327, 2329.
	Ileana					
	Regina Maria					
	Others					
12	Bahna (Basna)					Baths. Ref. 2318.
13	Govora					Resort. Ref. 2308.
14	Calimanesti (Calimanescii)					Do.
15	Curtea de Argesh					Used by Romans. Ref. 2308.
16	Sinaia					Resort. Ref. 2308.
17	Slanic					Saline mine water. Baths. Refs. 2308, 2314.
18	Lake Sarat (near Braila)					Ref. 2308.
19	Tekir Ghiol, near Constantsa.					Do.
20	Mangalia					Radioactive. Refs. 2315, 2319.

SPAIN

Spain occupies about five-sixths of the Iberian Peninsula, which consists mostly of a great plateau, limited on the north by the Pyrenees Mountains and the Cantabrian Mountains and on the south by the Sierra Morena. The plateau is traversed by four minor mountain ranges which separate the drainage basin of the Ebro River from that of the Duero River. The Ebro drains the northeastern part of the country and empties into the Mediterranean Sea; all the other main streams flow southwestward or westward to the Atlantic.

The plateau region and bordering mountains are underlain by a massif of ancient rocks, complexly folded and faulted, and form a part of the Hercynian tectonic region of southern Europe. Archean granite, gneiss, and schist form much of the Pyrenees Mountains. Paleozoic sedimentary rocks constitute other main mountain masses. Sedimentary strata of Mesozoic age border most areas of older rocks and also cover large areas in south-central Spain. In the north, northeast, and southeast, large areas of older rocks are overlain by marine Tertiary strata. Volcanic rocks are present in only minor areas. The locations of thermal springs are shown on figure 40, and the available information on them is given in the table below.

Thermal springs in Spain

[Data chiefly from ref. 2346. Location of unnumbered spring not identified]

No. on fig. 40	Name or location	Temperature of water (° C)	Flow (liters per minute)	Total dissolved solids (ppm)	Principal chemical constituents	Associated rocks	Remarks and additional references
1	Carballo:						
	Baños Viejos (Old Baths).	33–40		404–418		Granite	3 springs. Bathing.
	Baños Nuevos (New Baths).	26		342; 375	Na, SO_4	do	2 springs. Bathing. Refs. 2342, 2343.
2	Ortejo	28–42		651–2,009	Na, SO_4		4 springs. Resort. Ref. 2343.
3	Aguas de Bejo	25		261			Ref. 2343.
4	Caldelas de Reyes	39.4 (max)		Low	Na, Cl, SO_4		4 springs. Resort. Ref. 2344.
5	La Toja, on island of same name.	60 (max)	400	Low			Several springs. Resort. Ref. 2344.
6	Caldas de Cuntis	60 (max)		Low			Several sprigns. Resort.
7	Puente Caldas, 15 km east-southeast of *Pontevedra*.	30		Low			Includes nearby warm spring of San Justo de Sacos. Resort. Ref. 2344
8	Caldas de Tuy	47–50		Low			Several springs in bed of Río Miño. Resort. Ref. 2344.
9	Carballino	28	100	(1)	Na, SO_4		Resort. Ref. 2344.
9	Polgras	24	Small				
9	Parada de Achas	32	Small				
10	Lugo	43	120	(1)	Na, SO_4	Silurian strata	Resort.
11	Caldas de Oviedo	43	Large	(1)	HCO_3	Carboniferous limestone	Contains nitrogenous matter. Resort
12	Buyeres de Nava	21–25	62.5		Ca, SO_4		3 springs. Resort.
13	La Hermida	50–60	Large		Na, Cl	Contact of Triassic strata with Carboniferous limestone.	Several springs. Resort.

See footnote at end of table.

LANZAROTE

(Easternmost of Canary Islands)

SOFREM
M.T. 5. Ex.

INTRODUCTION

I - INTRODUCCION

After the difficult laborious realization in Lanzarote for the exploration
Después de los trabajos realizados en Lanzarote para la exploracion
geothermal island and sounding boring deep La 1, a model geologic
geotérmica de la isla y del sondeo profundo La 1, el modelo geologico
has held whom what to be reviewed, revised.
ha tenido que ser revisado.

For to obtain more above about the geology deep of the isle
Para conseguir mas informaciones sobre la geología profunda de la isla,
we to proceed with a
se decidió proceder a un estudio magneto-telúrico.

The goals of the present are
La meta de aquel estudio era :

with
1) Comparar los resultados en la zona de la Montaña del Fuego donde se
known surface and boring
conocen anomalías térmicas en la superficie y en la zona del sondeo
deep
profundo.

about around for search
2) Estudiar varias regiones alrededor de la zona térmica para buscar
which putrify? are related with
anomalías magneto-telúricas que podrían ser relacionadas con un
deposit ?
yacimiento geotérmico.

many
El método M.T.-5-E.X. ha sido utilizado con éxito en muchas zonas geotér-
since More recently other MT methods have been used
micas desde 1973. Más recientemente, otros métodos M.T. se utilizan
countries Proper, exact the difficulty of the M.T. for giving with precisil
en varios paises. Debido a la dificultad del M.T. para dar con precision
information relative to the depth of the anomalies, the study
informaciones relativas a la profundidad de las anomalías, el estudio
M.T.-5-E.X has been completed by an electro-magnetic specialization
M.T.-5-E.X. ha sido completado por un método electro-magnético
in the resolution of the surface resistivities
especializado en la determinación de las resistividades superficiales.

The S.P.E.G. offers the service of SOFREM EM frequency sounding
La S.P.E.G. ofrece el servicio del SOFREM (sondeo frecuencial electro-
employed after many years (as more or less developing
magnético) empleado desde hace muchos años (como sistema mas o menos
system and that gives similar results to those that could be
desarollado) y que da resultados semejantes a los que pueden ser
obtained by classic electric soundings. Notwithstanding the SOFREM permits
obtenidos por sondeos eléctricos clasicos. No obstante, el SOFREM permite
major rapid measurement, offers better spacial precision and gives
mayor rapidez de medida, ofreciendo mejor precisión espacial y dando
various classes of apparent resistivities
varias clases de resistividades aparentes.

Kenya France not US

ábaco = abacus ⇒ interpretation ?
inspection ?
matching
intersection ?

The contract between ENADISMA and S.P.E.G. was signed the 13th of November, 1980
El contrato entre ENADIMSA y S.P.E.G. se firmó el 13 de Noviembre de 1980.

The program of ... The
El programa de trabajo ha sido organizado por ENADIMSA. El programa
initial provided a survey of about
inicial estaba previsto sobre una superficie de unos 90 kilómetros
square
cuadrados.

A first study for the location of a deposit
Un primer estudio al fin de localizar un yacimiento necesita generalmente
one station while
una estación por km2, mientras que la determinación de un sitio favorable
drilling
para la perforación necesitaría 3 o 4 estaciones por km2.

Generally
Generalmente las estaciones dipolos están dispuestas en perfiles y pueden
ser entre el doble y cuatro veces el número de estaciones M.T.

In we have encountered a region very dificult for the studies
En Lanzarote hemos encontrado una región muy difícil para los estudios
The are as follows.
M.T. y Dipolo. Las dificultades son las siguientes :

Great difficulty of penetration in the zones of the ... To do many
- Gran dificultad de penetración en las zonas del malpais. Hacer muchas
M.T. stations in the zone of the ? has been very slow, until two
estaciones M.T. en la zona del malpais habría sido muy lento, hasta
days by station by the necessity of transporting the equipment
2 días por estación (por la necesidad de caminar llevando el equipo
by hand in very difficult conditions
en la mano en condiciones muy difíciles).

Impossible to read signal
- Imposibilidad de registrar señal M.T. significante en las zonas
although ground high greater than 40°C
térmicas : cuando la temperatura del suelo es alta (superior a los 40°C),
rocks
la roca volcánica se encuentra completamente seca, la resistancia
terrain ∞ and the noise very strong causing
electrica del terreno es infinita y el ruido telúrico muy fuerte, causado
phenomenal surface wind? remaining
por cualquier fenómeno superficial (viento), queda sin relación con
el Magneto-Telúrico.

The wind that was very weak the first days of the campaign end of
- El viento que era muy debil los primeros días de la campaña (fines de
November was later strong and reached a level of storm during
Noviembre), fue luego fuerte y alcanzó un nivel de tempestad durante
some days of January The wind augmented the noise general and as a
unos días de Enero. El viento aumenta el ruido general y como
consequence reduced the general quality of the registers
consecuencia reduce la calidad general de los registros.

The natural signal remains a fundamental criteria of quality It is certain
- La señal natural queda como criterio fundamental de calidad. Es cierto
that the solar activity directly influences about the level of the M.T.
que la actividad solar influye directamente sobre el nivel de la señal
signal registered Generally the level of the signal remained small.
M.T. registrada. Generalmente el nivel de la señal quedó bajo.

The study have been divided in 3 parts, and because of the wind? of the
El estudio ha sido dividido en tres partes y, a causa del viento, del
level of the signal and of the geographic situation, the conditions have been
nivel de la señal y del sitio geografico, las calidades han cambiando : changing

- A finales de noviembre, las estaciones son de calidad muy buena (promedio de calidad 2).

- Diciembre, las estaciones son de calidad 2 al principio y luego bajan a 4 (16 y 18 de Diciembre).

- Enero, la calidad es generalmente baja con dos maximos a 3 (el 16) y a 2,5 (el 22). (Veáse la figura 1).

Because of the difficulties encountered (difficulty of access large number
A causa de las dificultades encontradas (dificultad de acceso, gran número
of non processable) a number of sations used in this
de estaciones no procesables) el numero de estaciones utilizables en el
study have been reduced 40 from 90 km², with the
estudio ha sido bajo (40 para 90 km2), con el inconveniente que muchas
and therefore the relation between the
zonas quedan desconodicas y que las relaciones entre las diferentes
difficult to comprehend
anomalías son a veces difíciles de comprender. Sin embargo la mayoría
de las preguntas pedidas han podido ser contestadas.

The dipole frequency soundings over taken on three profiles spaced 300 m
El Dipolo SOFREM ha sido praticado en tres perfiles espaciado de 300 metros
between
entre estaciones.

The 88 Dipole stations are are small enough numerous in comparison
Las 88 estaciones Dipolo son también demasiado poco numerosas en comparación
with the superficial total of the study. For the Dipole, also have faulted
con la superficie total del estudio. Para el Dipolo, también nos ha faltado
time. An East-West profile has been easy to realize, that it
tiempo. Un perfil Este-Oeste hubiera sido facil de realizar, lo que
has permitted it to have 110 stations about 45 km² of surficient (?)
hubiera permitido tener unas 110 estaciones sobre unos 45 km2 de superficie.
The zones north and N.E. of the study have not been covered by the Dipole
Las zonas norte y N.E. del estudio no han sido cubiertas por el Dipolo
and in these zones we donot have sufficient about the anomalies
y en estas zonas no tenemos datos superficiales sobre las anomalías
that been shown to exist
que parecen existir.

Remarks about the Time and Personal

II - REPARTICION DE LOS TIEMPOS Y PERSONAL

began . at on and returned apon
Los operadores llegaron a Lanzarote el 21 de Noviembre y regresaron en
end of the mission January The work was interrupted between
fin de mision el 29 de Enero. El trabajo fue interrumpido entre el 24 de
January Christmas
Diciembre y el 10 de Enero por Navidades, sin facturación según un acuerdo común entre ENADIMSA y S.P.E.G.

days
El tiempo de presencia de los operadores y del equipo en Lanzarote fue de 52 días (33 más 19 días).

the time of invoice was
El tiempo de facturación fue de 45 dias.

La diferencia se explica por averías y por ensayos del equipo. Entre el 3 y el 7 de Diciembre, una avería del módulo de adquisición hizo perder cuatro días.

seven days
Las 55 estaciones M.T. se han registrado durante 26 días y las 88 estaciones Dipolo durante siete días.

La campaña de topografía fue iniciada por el personal S.P.E.G. para ganar tiempo, luego el trabajo fue realizado por un topógrafo professional de ENADIMSA.

El personal de ayuda para la preparación y la instalación de las estaciones estaba compuesto de cinco obreros locales. La organización general administrativa corría a cargo del representante local de ENADIMSA, que permitió abastecer los materiales : bentonita, estacas, coches, asi como los obreros y que resolvió los problemas de alojamiento, almacenamiento, autorizaciones etc...

III - ORGANIZACION DEL M.T. Y RENDIMIENTO

El programa de ENADIMSA ha sido respetado para la implantación de las
Each had a point two lines of
estaciones. Cada estación tiene un punto central O, dos líneas de 100
meters OX and OY degrees hundredth
metros OX y OY. El ángulo OX, OY es de 100 grados centesimales.
90° ?

El primer equipo hace los agujeros, prepara la mezcla de lodo (bentonita y agua) y pone los 5 electrodos en X, Y y en O.

El segundo equipo acompaña el laboratorio en el coche Land Rover.

Casi todas las estaciones fueron registradas con el equipo en el laboratorio. El equipo salió sólo dos veces el 25 de Enero (estaciones 11 A y 41 A).

El laboratorio estaba compuesto de :

- 3 captores magnéticos (magnetometers) para registrar las 3 componentes Hx, Hy, Hz.
- 5 electrodos.
  2 para (for) Ex, 2 para (for) Ey y uno para (and one for) la tierra (ground).
- 1 módulo de amplificación (con diez amplificadores).
- 1 módulo de adquisición (doble) numérico de cassettes.
- 1 módulo registrador gráfico (diagram) de control.

Los electrodos estaban unidos al laboratorio por medio del cable telúrico,
the connectors for cables have a special armor, The connectors cables have insulation as a
los captores por cable especial armado. Los captores se instalaron con
media magnetic and sighting optics
precaución por medio de brújula y visor óptico.

There are 2 classes of readings. The readings of the C.N.R.S., although
Teníamos dos clases de captores. Los captores del C.N.R.S., aunque más
very sensible, are very large (2m) for the type of terrain, they were
sensibles, eran demasiado largos (2 m) para el tipo de terreno, no
not utilized
fueron utilizados.

The installation time was generally large, depending on the difficulty
El tiempo de instalación fue generalmente largo, debido a la dificultad
of the terrain and to the limited time of the campaign (small personal experimenting).
del terreno y al escaso tiempo de campaña (personal poco experimentado).
The registration time was of hour and minimus measurement for each station.
El tiempo de registro fue de hora y media mínimo para cada estación.

When the signal was insufficient, the same register was repeated or the time
Cuando la señal era insuficiente, el mismo registro se repetía o el tiempo
was increased
era aumentado.

La distancia entre Arrecife, donde se alojaba el personal, y el terreno, la dificultad de acceso, el tiempo largo de instalación y la calidad baja
explain the yield raw
de la señal explican el rendimiento bruto M.T. de 55 estaciones en 23 días de registro (2,39 por día).

The rate raw
El rendimiento bruto Dipolo ha sido de 12,6 estaciones por día (88 estaciones en 7 días). La diferencia entre días de registro (23 + 7) y días de facturación (45) se explica por los días de preparación, de mobilización
Sunday
y los domingos.

IV - METODO DIPOLO (SOFREM)

(Dipolo Sofrem)

Penetration depth @ 560 Hz

$\rho_a = 100\ \Omega\text{-m};\ \sqrt{\frac{100}{560}} \times 356 = 150\ m$

$\rho_a = 10\ \Omega\text{-m};\ 356\sqrt{\frac{10}{560}} = 47\ m.$

$\rho_a = 16;\ 356\sqrt{\frac{16}{560}} = 60\ m.$

$\rho_a = 800\ \Omega\text{-m};\ 356\sqrt{\frac{800}{560}} = 425\ m$

IV-1 PRINCIPIO

the dipole methods used
El método Dipolo utilizado (SOFREM) pr
of the
cial de la resistividad eléctrica del

An transmitter e.m.
Un emisor electro-magnético de muy baja frecuencia y constituído por un Dipolo magnético con eje vertical está dispuesto en la superficie del suelo.

A receiver situated a certain distance from the transmitter as well as in the ground measure em field transmitted
Un receptor situado a cierta distancia del emisor, también en el suelo, permite medir las componentes del campo electro-magnético emitido.

The manner of sounding the subsoil is similar to the magnetotelluric method. The penetration more or less large of the radiation in the subsoil conductor is a function of the frequency: the smallest frequencies and the terrain of higher resistance correspond to the greater penetration.
La manera de sondear el subsuelo es parecida al método magneto-telurico. La penetración más o menos grande de la radiacion en el subsuelo conductor es función de la frecuencia: las frecuencias más bajas y los terrenos más resistantes corresponden a la penetración mayor.

IV-2 OPERACION

OPERATION

In the emission station a monocable ring is unrolled. Then, this ring is successively fed by running different frequencies. It is possible to realize around the ring various drillholes utilized stations of measurement chosen by the utilization
En la estacion emisora un anillo monocable está desenrollado. Luego, este anillo está alimentado sucesivamente por corrientes de frecuencias diferentes. Se puede realizar alrededor del anillo varios sondeos utilizando estaciones de medida escogidas por el utilizador.

A radio connection permits the communication between the operators located in the station transmitter and receiver
Un enlace radio permite comunicar entre los operadores sitos en la estación emisora y receptora.

At each 3 1
En cada estación, las amplitudes de las tres componentes rectangulares
are measured afterward of the other for each
del campo electro-magnético se miden una después de otra para cada
transmitted covering
frecuencia emitida (cubriendo 6 a 8 octavas).

Las tres componentes son :

- magnética vertical Hz
- magnética radial Hx
- eléctrica transversal Ey

The diameter of the ring and the emission-receptor distance are chosen
El diametro del anillo y la distancia emisor-receptor son escogidos
according to the resistivities and the depths encountered
segun las resistividades y las profundidas encontradas.

In the present campaign,
En la presente campaña, después de los ensayos iniciales, las estaciones receptoras se situaron a lo largo de perfiles y los
ring spacing between
anillos de emision centrados sobre estos, siendo el espacio entre
stations of 300 m and transmitter-received of
estaciones de 300 metros y la distancia emisor-receptor de 600 metros.

translate

The diameter of the ring has been reduced to 60 meters to cause the
El diametro de los anillos ha sido reducido a 60 metros a causa de la
great difficulty for unrolling the cables in the ___, obligated
gran dificultad para desenrollar los cables en el malpais, obligando
to reduce the potential of emission, and as a consequence, diminishing
a reducir la potencia de emision, y como consecuencia, disminuyendo
the signal/noise relation of the measurement
la relación señal/ruido de la medida.

Also, the cause of the difficulty that there is in traveling by the ___,
También, a causa de la dificultad que hay en caminar por el malpais,
the yield of the equipment only had been able to be of 12.6 stations per day.
el rendimiento del equipo solo ha podido ser de 12,6 estaciones por día.

Generally the operation normally need three operators:
Generalmente las operaciones normales necesitan tres operadores :
one on the transmitter two on the receiver, more the assistance of
uno en el emisor, dos en el receptor, más la asistencia de personal
auxiliary personell for bring the equipment and unrolling the transmitter ring
auxiliar para llevar el equipo y desenrollar el anillo de emisión.

In LANZAROTE, the first drawn(?) were realized by four
En LANZAROTE, los primeros perfiles fueron realizados por cuatro
operators, while that the ultimate drawing(?) was realized by two
operadores, mientras que el ultimo perfil fue realizado por dos
operators, in the two cases with help of the auxiliary personell
operadores, en los dos casos con ayuda de personal auxiliar.

The stations are Located on the maps by aerial photos
Las estaciones se localizaron en los mapas o en las fotos aéreas
and with a compass.
y se orientaron con brujula. Las distancias fueron medidas con topofil CHAIX (Mapa N° 1).

IV-3 CARACTERISTICAS DEL APARATO SOFREM

El equipo SOFREM es portatil y comprende :

Transmitter of sin wave

- Un emisor de corriente sinusoidal con once frecuencias fijas (de 17,5 hz a 17920 hz, de octava en octava) pilotadas con cuarzo.

High freq. ie AMT range

17.5 — 17,920 hz

Low power, 150 watts

La potencia máxima de emisión es de 150 wat.

The transmitter is fed by an electrogenerator of 400 watts

El emisor está alimentado por un grupo electrógeno de 400 wat.

The ring of Transmitter has a diameter of 60 meters (with a single coil,

El anillo de emision tiene un diametro de 60 metros (con una sola espira).

An apparatus of measurement with 11 preselected fixed frequencies fed by batteries

- Un aparato de medida con once frecuencias fijas preseleccionadas, alimentado por pilas.

1 a magnetic detector by induction double (2)

- Un captor magnético a inducción doble.

Two electrodes of measurement of the country electric distances of five meters

- Dos electrodos de medida del campo eléctrico distantes de cinco metros.

The reading made by a voltmeter with liquid crystals

- La lectura se hace por un voltímetro con cristales líquidos.

The total weight of the equipment, cable of emission included, is of aproximently ~50 Kilos.

El peso total del equipo, cable de emisión incluído, es de cincuenta kilos aproximadamente.

IV-4 EXPLOTACION DE LAS MEDIDAS

For each station

1) Para cada estación - sondeo, se usa una hoja de explotación. Las amplitudes de las componentes de campo Hx, Hz y Ey son medidas y anotadas, lo que permite calcular una resistividad aparente para las frecuencias $\omega/2\pi$ utilizadas :

$$\rho_a = \frac{K}{\mu_o \omega} \left(\frac{Ey}{Hx}\right)^2$$

La permeabilidad magnética del subsuelo se asimila a la del vacio sea μ_o.

geometric factor

K es un "factor de proximidad" de la fuente que en el caso teórico de un subsuelo homogéneo, permitiría traer la resistividad aparente al valor obtenido en el caso del sondeo de impedancia de superficie en ondas planas bajo incidencia normal (sondeo magneto-telúrico ideal).

El factor K se define en función de la relación de las amplitudes $(\frac{Hx}{Hz})$.

La medida se efectua en posición "estación de recepción". La experiencia muestra que los resultados de un sondeo utilizado de esta manera son función esencialmente de las resistividades del subsuelo en los alrededores de esta estación.

2) También se calcula una resistividad aparente por inclinación del campo magnético.

$$\rho'_a = \frac{K' R^2 \mu_o}{g \, (\frac{Hx}{Hz})^2}$$

$C = \frac{h}{\rho}$ mhos

h thickness in m

ρ in ohm-m

between Tx and receiver

R es la distancia entre emisor y receptor.

another distance factor

K' es otro factor de proximidad función de

Esta manera de explotación permite una investigación que abarca
important between Tx and Re
un volumen importante de terreno entre emisor y receptor.
The data are in this case plotted in an intermediate
La medida esta, en este caso, aplicada en "posición intermedia",
midway between Rc Tx
es decir a igual distancia del receptor y del emisor.

In the case of a homogeneous subsurface or a horizontal stratification
En el caso de un subsuelo homogéneo o de estratificación horizontal,
the mean of equal values near and
la medida da iguales valores para ρ_a y ρ'_a.

variations lateral
En el caso de que el subsuelo presente variaciones laterales de
resistivity
resistividad (buzamiento fuerte, contacto anormal, falla, filón, dike etc) la experiencia muestra, al contrario, que ρ_a y ρ'_a toman valores diferentes para el mismo dispositivo emisor-receptor.

The apparent resistivities ρ_a measured by large of a profile
Las resistividades aparentes ρ_a medidas a lo largo de un perfil
marked since, by a very fine manner, the lateral variations of
marcan pues, de manera muy fina, las variaciones laterales de
resistivity, eventually accented by the "anomalies of contact."
resistividad, acentuadas eventualmente por las "anomalías de
The resistivity ρ_a', on the contrary, is less sensitive
contacto". La resistividad ρ_a', al contrario, es poco sensible
to the presence of an anomaly of resistivity although this is
a la presencia de una anomalía de resistividad aunque esta sea
strong always that is of small lateral extention.
fuerte siempre que sea de poca extención lateral.

The important practical result is that the resistivity ρ_a'
El resultado práctico importante es que la resistividad ρ_a'
(by inclination of the magnetic countion) indicates the median resistivity
(por inclinación del campo magnético) indica la resistividad
of the formation between emisor and receptor, while the
media de la formación entre emisor y receptor, mientras que la
resistivity ρ_a (by superficial impedance) gives a fine sketch
resistividad ρ_a (por impedancia de superficie) da una delineación
of the vertical anomalies as the abnormal contacts or faults
fina de las anomalías verticales como los contactos anormales o
las fallas.

To calculate an "apparent penetration" by each frequency F according to
3) Se calcula luego una "penetración aparente" por cada frecuencia F
the relation:
según la relación :

$$p_a \simeq 356 \sqrt{\frac{\rho_a}{F}}$$

$p_a \simeq \delta/\sqrt{2} = 356\sqrt{\frac{\rho_a}{F}}$

The depth is the horizontal limit of a subsoil
Esta profundidad es la del límite horizontal de un subsuelo
with two terrains, F and ρ_a are since the coordinants of the "cross"
con dos terrenos, F y ρ_a siendo pues las coordenadas de la "cruz"
of the abacus of apparent resistivity.
de los ábacos de resistividad aparente.

depth of penetration is interesting because it gives in the
Esta profundidad de penetración es interesante porque da en el
case of two terrains an immediate interpretation.
caso de dos terrenos una interpretación immediata.

Only changing by a numeric coefficient of the depth of
Sólo cambia por un coeficiente numérico de la profundidad de
penetration theoretically defines in a subsoil of resistivity ρ
penetración teórica definida en un subsuelo de resistividad ρ
by
por

$$p = \sqrt{\frac{2\rho}{\mu_0\omega}} \simeq 503\sqrt{\frac{\rho}{F}}$$

Literal transl.
pgs 11-13

IV-5 ESTADISTICAS

Número total de estaciones de sondeo	88	
Número total de anillos desenrollados	44	
Distancia media entre estaciones	300 metros	
Longitud de los perfiles	21 km	
Longitud del perfil repetido (ensayos)	1,75 km	1.75
Número de días de medida	7	
Número medio de estaciones/día	12,6	12.6

IV-6 RESULTADOS

For a large majority of the soundings the curve of app resistivity v.s. frequency
Una gran mayoría de los sondeos da una curva de resistividad
in function of the frequency the type "Two layer earth" with
aparente en función de la frecuencia del tipo "Dos terrenos" con
a deep conductive layer.
capa profunda conductora.

The figure 2 shows the values of apparent resistivity ρ'a for the soundings drill holes
La figura 2 muestra los valores de resistividad aparente ρ_a' para
505 to 512
los sondeos 505 a 512.

An interpretation by abacus of the median curve locates gives
Una interpretacion por abaco de la curva media conseguida da
resistivities of 800 Ωm respectively for the surface layer
resistividades de 800 Ω.m. respectivamente para los dos terrenos,
which extends to 190 m above the deep layer
el límite estando a 190 metros de profundidad.

The mean altitude of these stations is 201 meters, and we are
La altitud media de estas estaciones es de 201 metros, y se puede
able to conclude that the conductor level that constitutes the second
concluir que el nivel conductor que constituye el segundo terreno
terrain is very near the level of the sea. With this, one is able
esta muy cerca del nivel del mar. Esto se puede interpretar como
to interpret as an invasion of sea water or more probably by a
una invasión de agua de mar o más probablemente por un nivel
damp level in hydrostatic equilibrium with the sea. So one is able to
húmedo en equilibrio hidrostatico con el mar. Así se puede aceptar
accept that this majority of soundings gives an investigation until the level of
que esta mayoría de sondeos da una investigación hasta el nivel
the sea.
del mar.

Nevertheless we are able to note two types of exceptions for this
Sin embargo se pueden notar dos tipos de excepciones para esta
family of drill holes:
familia de sondeos :

The station 536 to the south of the mean sample profile n practically
1) La estación 536 al sur del perfil medio muestra un terreno practi-
homogeneous terrain, the substratus conductor is not perceptable
camente homogéneo, el substrato conductor no siendo perceptible
in this place,
en este lugar.

Some sounds, particularly in the Montaña del Fuego,
2) Algunos sondeos, particularmente en la Montaña del Fuego,
present curves of resistivity and are completely different from
presentan curvas de resistividad y se salen completamente de
a classic tabular model.
un modelo clasico tabular.

The three crossections have been drawing with the resistivities ρ_a and ρ'_a
Los tres perfiles han sido dibujados con las resistividades ρ_a y ρ'_a
for two frequencies. A double anomaly in form of W are able to see
para dos frecuencias. Una anomalía doble en forma de W se puede ver
on the resistivity ρ_a, particularly in the central crossection.
en la resistividad ρ_a, particularmente en el perfil central.

Two maps of equal resistivities have been drawn for the frequency of
Dos mapas de iso resistividades han sido dibujados para la frecuencia
560 hertz. For this mean frequency, the means are excellent in
560 hertz. Para esta frecuencia media, las medidas son excelentes en
all of this study,
todo el estudio, esta frecuencia corresponde en todas partes a una
penetration as deep as sea level
penetración hasta el nivel del mar.

The equal-resistivity ρ'_a map (Map N° 3) is related with the
El mapa de iso-resistividad ρ'_a (Mapa N° 3) está relacionado con la
mean resistivity of the volcanic rocks. This sample map shows a
resistividad media de las rocas volcanicas. Este mapa muestra una
very regular descent of resistivity of East to West, from the Montaña
bajada muy regular de resistividad de Este a Oeste, desde la Montana
del Fuego until the sea. That renders the difference of altitude and furthermore
del Fuego hacia el mar. Eso traduce la diferencia de altitud y además
shows values of high resistivity in the Montaña del Fuego.
muestra valores de resistividad maximos en la Montana del Fuego.

The equal-resistivity ρ_a map (Map N° 2) is very different from the first.
El mapa de iso-resistividad ρ_a (Mapa N° 2) es muy diferente del primero.
The map presents very strong conducting axes that we are able to interpret
El mapa presenta ejes conductores muy fuertes que pueden interpretarse
as fractures or practically vertical contacts.
como fracturas o contactos practicamente verticales.

V - PROCESAMIENTO DE DATOS DE LAS ESTACIONES M.T.

Los 55 registros M.T. han sido cuidadosamente estudiados y varias verificaciones fueron hechas con la computadora.

Durante esta verificación se constató que 11 registros realizados entre el 3 y el 6 de Diciembre no podían ser utilizados (estos no estan dentro de los 55).

Entre las 55 estaciones disponibles, se ha constatado que la calidad de 15 registros era demasiado baja (calidad 5). Cuando la señal M.T. no alcanza un nivel limite, las correlaciones entre campo magnético y campo telúrico no se pueden asegurar. Las estadísticas hechas sobre las relaciones Ex/Hy y Ey/Hx no dan valores constantes. Es decir que la precisión es mala y que los valores encontrados serían distintos si los registros se hubieran realizado en otro momento.

Las 15 estaciones malas (11, 19, 20, 21, 26 A, 42 A, 46, 54, 56 A, 57, 59, 60, 62, 70, 77) no están utilizadas en el presente informe y no son facturadas. Algunas han podido ser registradas otras veces.

Las 40 estaciones que quedan han sido todas procesadas con el sistema M.T.-5-E.X. que permite mayor calidad, indicando la dirección principal y que generalmente da los mejores resultados en geotérmia.

Con la intención de estudiar lo que hubiera sido posible con el sistema de procesamiento clásico (armonico) un ensayo de procesamiento se realizó para algunas estaciones. Los resultados no son muy buenos y son dados solo para indicación.

VI - RESULTADOS

VI-1 ADQUISICION DE LOS RESULTADOS

La manera de utilizar los datos obtenidos viene explicada en el fascículo en francés titulado : "Mode d'Interprétation de la M.T.-5-E.X." que acompaña este informe (Anexo 1).

Los registros númericos han sido procesados mediante el programa habitual M.T.-5-E.X. que utilize un análisis de frecuencia con soluciones de tipo exponencial.

Cada registro se ha analizado mediante los siguientes documentos :

- registro gráfico de control ;
- dibujo de ciertas partes del registro numérico para verificación ;
- lista de los resultados incluyendo los diferentes valores y los datos estadísticos que permiten el control de calidad ;
- lista de los resultados (Anexo 2) ;
- curvas de resistividades aparentes en función de las diferentes constantes de tiempo τ utilizadas (Anexo 3).

Los 2 últimos resultados de cada una de las 40 estaciones retenidas en el estudio se entregan en fascículos independientes y se adjuntan al presente informe.

Por otra parte, las listas de los resultados del informe (Anexo 2) indican :

- la conductancia total tal y como se deduce a partir de una curva teórica, en mhos.

- la calidad de las estaciones.

VI-2 CALIDAD DE LAS ESTACIONES

El primer criterio de calidad aceptado viene dado por los observers de terreno quienes perciben :

- El ruido debido a causas exteriores, viento, lluvia, perturbaciones etc.. De esta manera se ha deducido la imposibilidad de registrar en las zonas térmicas de la Montaña del Fuego ;

- La falta de correlación entre diferentes trazas (la fuente de perturbación electro-magnética pudiendo estar accidentalmente demasiado cerca no puede considerarse como aceptable) ;

- El bajo nivel de la señal.

En el terreno, durante el despojo de datos, se decidió por simple analisis del gráfico volver a empezar o interrumpir una estación M.T. no podiendo considerarla por válida.

Los demás criterios de calidad vienen dados por elementos estadísticos variados : número de muestras utilizadas, número de familias de muestras utilizadas, porcentaje de resultados idénticos guardando un margen de 5 % sobre los valores utilizados, filtrage aplicado en el tratamiento, variaciones de los resultados cuando se analizan diferentes estudios del registro, y por último la forma de las curvas de resistividades aparentes (Anexo 3).

La experiencia muestra que un rigoroso control de la calidad de los registros era la clave de que el Magneto-Telúrico fuera fiable, teniendo en cuenta de que la señal natural varia de manera aleatoría y que las perturbaciones proximales son a veces dificiles de discernir en el terreno.

Quality of MT soundings

Ha sido posible clasificar las estaciones en cuatro calidades que corresponden a cuatro tipos de estadística :

1 Excelente "

2 Muy bueno Very Good

3 Bueno = Good

4 Regular = Average

La calidad 1 es la calidad superior y corresponde a los mejores resultados.

La calidad 4 es la calidad inferior aceptada ; la precisión de los valores conseguida para estas estaciones es baja (20 %) y los valores están dados solo como indicación general. No es posible decidir un sondeo sobre estas estaciones.

9 estaciones son de calidad 1 : Excellent 9
2, 4, 23, 36, 37, 38, 40, 43, 72.

6 estaciones son de calidad 2 : Very Good 6
1, 35, 39, 48, 55 A, 65.

15 estaciones son de calidad 3 : Good
3, 6, 7, 16, 17, 20 A, 22, 45, 58, 64, 73, 75, 24 A, 28 E, 74.

10 estaciones son de calidad 4 : Average 10
5, 9, 52, 63, 30 B, 31 A, 26 B, 11 A, 41 A, 29 A.

La figura 1 muestra los periodos más favorables de la señal M.T. ; es de notar que la calidad de las estaciones ha bajado mucho después del 12 de diciembre. Esta baja corresponde a la disminución de la señal natural pero también al viento puesto que aumenta mucho el ruido. Es probable que a partir del 12 de Diciembre hubiera sido preferible utilizar captores más sensibles (del C.N.R.S.), pero no se podía porque estos captores eran demasiado largos (2 metros en vez de 60 centímetros).

En el futuro, utilizaremos captores intermedios de 1 metro que ahora están a disposición.

VI-3 CONDUCTANCIAS TOTALES

Se trata de conductancias aparentes longitudinales. El método rápido de cálculo de estas componentes supone que las curvas de resistividad aparente sean rectas crecientes de pendiente 2.

De hecho, hemos examinado cada curva del Anexo 3 y las hemos superpuesto a curvas teóricas de conductancias totales conocidas, lo que permite : examinar cada curva y tomar conciencia de las anomalías eventuales y compensar las pequenas variaciones debidas a constantes de tiempo menos precisas. Las conductancias totales así obtenidas son las que se utilizan en el mapa de iso-conductancias (Mapa 5).

VI-4 CRITERIOS DE CILINDRICIDAD

Se han examinado en cada estación los criterios de tabularidad y cilindricidad.

De hecho, las estaciones tabulares o cási tabulares son excepcionales.

La mayor parte de las estaciones están polarizadas, pudiendo indicar la dirección principal y los criterios de cilindricidad.

Sabemos por otra parte que los resultados de las estaciones no cilíndricas y no tabulares han de ser utilizados con precaucion.

Estos criterios se ven facilmente en las listas de los resultados (Anexo 2).

Como ya hemos expuesto anteriormente el M.T.-5-E.X. puede procesar sin dificultad el problema de los terrenos tabulares. También permite por extensión calcular cuantitativamente valores de resistividad aparente, y por lo tanto de conductancia aparente, para la dirección principal (conductancia longitudinal) en el caso de que la distribución de resistividades-profundidades admita un eje de simetria (caso cilíndrico). Hay que tener en conocimiento que en las regiones volcánicas o tectonicamente complejas, que se analizan habitualmente en exploración geotérmica, existen estaciones M.T. que no son ni tabulares ni cilíndricas. Para estas estaciones, la teoría no garantiza resultados perfectamente repetitivos. Todos los valores de conductancia longitudinal marcados en el Anexo II y en el mapa N° 5 son pues valores indicativos para estas estaciones no cilíndricas.

If we 5
Si se divide la región estudiada en cinco zonas, encontraremos las estaciones cilíndricas siguientes : need literal translation

1 - Zona Noreste (al Este de la Caldera Blanca). Las estaciones 63, 64 y 48 son francamente cilíndricas. Por el contrario la estación 45 es francamente menos cilíndrica y es seguro que la geología de esta zona es compleja.

La anomalía conductora encontrada en este punto sería dudosa si no pareciera confirmarse por la estación 64. Veremos no obstante que un accidente pasa probablemente a proximidad de la estación 45.

Como es costumbre encontrar, la estación 45 no presenta ninguna dirección principal bien marcada y por lo tanto sólo es de calidad 3.

Esta zona sólo esta cubierta por 4 estaciones, lo que supone un numero muy bajo para los 14 km2 que mide.

2 - Zona Norte (al Norte de la Montaña del Fuego). Las estaciones 65, 20 y 22 son cilíndricas.

3 - Zona central o de la Montaña del Fuego. No se conoce evidentemente nada en las zonas termales ya que no ha sido posible registrar.

Las estaciones 72, 73 y 52 en el flanco Norte de esta zona son cilíndricas. Las estaciones 43, 9 y 75 al Sur del flanco son también cilíndricas. La estación 16 al Este de la zona es poco cilíndrica, no da ninguna dirección principal. Las estaciones 74 (al Sur) y 11 (en el centro) no son cilíndricas.

Es de señalarnoobstante que la dirección principal de la estación 11 esta bien marcada.

Aunque esta zona está cubierta por 9 estaciones en 10 km2, es lamentable que, a causa de la complejidad de la zona o de la calidad de la señal, no haya sido posible situar más estaciones que nos hubieran permitido comprender las relaciones entre los diferentes sectores.

4 - Zona Intermedia (y del sondeo profundo). En esta zona, las estaciones 1, 2, 3, 4, 7, 39 y 40 son cilíndricas, las estaciones 38, 6, 36 y 17 no lo son y las 5 y 37 lo son pero muy poco. No obstante, es de notar que la dirección principal no resulta claramente para las estaciones 1 y 39 que son cilíndricas y parece quedar muy marcada en las estaciones 5, 6, 37, 38 y 17 que no son cilíndricas o muy poco.

Mientras que la zona está estudiada alrededor del sondeo, es mucho menos conocida en el centro y al Sureste.

5 - Zona Occidental. Es la zona donde los resultados son los peores. Las estaciones 29, 30, 31, 41, 23 y 55 son por tanto cilíndricas, mientras que las estaciones 28, 24 y 35 lo son muy poco.

La estación 58, aislada, es perfectamente cilíndrica, es de calidad 3 y la dirección principal Norte-Sur resulta muy claramente.

Suitability for harmonic solution

VI-5 TRATAMIENTO POR SOLUCIONES ARMONICAS

Con el fin de monstrar los resultados que es posible obtener sin hacer intervenir los programas propios al M.T.-5-E.X., las estaciones N° 37 y N° 38 han sido procesados admitiendo que las curvas experimentales eran sinusoidales, y teniendo en cuenta que estaban situadas en una zona homogénea sin gran polarización y con una resistividad vertical fuerte (estaciones casi tabulares).

Las curvas de resistividad aparente en función de T periodo exprimido en segundos (para ROX y ROY) se anadieron al final del fascículo Anexo 3.

Al igual qua para el tratamiento exponencial, la curva obtenida es una recta creciente que muestra la influencia del zócalo. Nos encontramos pues en la parte de la curva bajo influencia del zócalo que se observa desde las primeras frecuencias calculadas (0,1 Hz).

Aunque las estaciones retenidas para hacer este ensayo son de excelente calidad, se observa una cierta dispersión de los valores sobre todo para las curvas ROX-38 y ROY-37. Se ven incluso las diferencias que existen entre el valor medio (puntos negros redondos) y las distribuciones estadísticas (rectangulos).

La abcisa de las curvas se exprime en T y no por $\sqrt{T}$ como en el ejemplo del Anexo 1 (figura 1 de la última pagina), la pendiente de la recta es pues de 1 en vez de 2.

Para las estaciones de menor calidad con polarización fuerte, los resultados obtenidos serían muy difíciles de interpretar.

VI-6 MODELOS DE BASE PARA LA INTERPRETACION

Hemos establecido algunos modelos teóricos y, suponiendo terrenos tabulares, se ha calculado la curva de resistividad aparente y por lo tanto conductancias totales (o conductancias totales longitudinales) que la M.T.-5-E.X. podría obtener.

También se ha hecho el mismo cálculo en soluciones armonicas para poder comparar con las estaciones 37 y 38 calculadas de esta manera y con las curvas SOFREM.

Varios casos se han simulado con las mismas profundidades y haciendo variar en cada caso las resistividades según las hipótesis retenidas.

L.T.

	Profundidades en metros Depth in m	Resistividades en Ω.m. Caso 1 compacto	Caso 2 permeable húmedo	Caso 4 permeable húmedo	Caso 3 caliente warm → hot
surface volc.	0 – 190	800	800	800	800
near sea level	190 – 340	16	16	16	16
below sea level	340 – 700	5	5	5	5
	700 – 850	10	0,7	10	10
	850 – 950	10	10	10	10
	950 – 1500	10	10	10	10
	1500 – 1700	20	1,4	1,4	20
	1700 – 1820	10	10	10	10
	1820 – 2100	20	20	20	20
	2100 – 2300	20	0,8	0,8	20
	2300 – 2550	20	20	20	20
	2550 – 2600	5	5	5	5
	2600 – 5000	50	50	50	10
	> 5000	10 000 o muy elevado			

<u>En el caso N° 1</u> : se ha supuesto que el corte geológico comprendria los mismos terrenos que los encontrados en el sondeo (hasta 2 600 m de profundidad). Por debajo hemos admitido, según los perfiles sísmicos efectuados en el mar, que el zócalo metamórfico o cristalino

L.T.

extremadamente resistente (superior a 10 000 Ω.m.) se alcanzaba aproximadamente a 5 000 m de profundidad. Entre 2 600 y 5 000 metros se ha considerado que la serie sedimentaria o debilmente metamórfica podía tener una resistividad media de 50 Ω.m.

La conductancia de esta serie teórica sería del orden de 280 mhos (Vease Figura N° 6).

<u>En el caso N° 2</u>, hemos considerado que aparecen depósitos en diferentes lugares de la serie geológica, preferentemente allí donde se notaron perdidas durante el sondeo, es decir, entre 700 y 800 m, 1 500 y 1 700 m y entre 2 100 y 2 300 m.

These levels encountered temperatures coincide of 38, 42, and 77°C
Estos niveles se encuentran a temperaturas conocidas de 38, 42 y 77°C
respectively. It is supposed that the resistivity of the water is that of sea
respectivamente. Se supone que la resistividad del agua es la del agua
water to the temperatures encountered of respectively
del mar a las temperaturas encontradas de 0.14 y 0.08 Ω.m. respectivamente.

Aplicando la fórmula dada en el Anexo 1 para cada capa-almacen se llega :

$$c = \frac{h \; Sw^n \; \phi^m}{a \; Rw}$$

donde : - Sw^n es igual a 1, no hay hidrocarburos y se supone que no hay gas.

- Rw es pues de 0.14 o 0.08 según el nivel.
- a y m se toman igual a 1 suponiendo que la fórmula de ARCHIE se aplica para un caso límite (fracturación importante con grandes fracturas y permeabilidad importante).

Esto viene a dar resistividades :

$$\rho = \frac{R}{\phi}$$

La porosidad de la capa superior se ha supuesto igual a 20 %, la de las capas inferiores igual a 10 %.

Hipotesis diferentes hubieran, evidentemente, podido retenerse pero de esta manera se habrían modificado los valores obtenidos en proporciones explicables.

Con este esquema, encontramos una conductancia de 850 mhos aproximadamente (Figura 7).

El caso N° 4 es un caso intermedio con un único depósito permeable, poroso, fracturado e invalido de agua de mar. La conductancia es de aproximadamente 650 mhos (Figura 8).

El caso N° 3 es un modelo donde el conjunto de la serie se considera sin porosidad o sin agua salada pero con una formación de base caliente (entre 2 600 y 5 000 m).

Sa sabe que la temperatura actua sobre la resistividad de una roca caliente y seca según una formula del tipo :

$$\rho = \rho_\infty \, e^{\frac{\beta}{T}}$$

donde : - ρ_∞ es el valor de resistividad para una temperatura igual a infinito y

- T es la temperatura en grados Kelvin.

Un aumento de temperatura de 100°C puede provocar una caída de la resistividad à 0,2 ρ.

Para nuestro modelo se ha tomado una resistividad de 10 Ω.m. entre 2 600 y 5 000 m.

En este caso, la conductancia total de la serie viene a ser de 470 mhos aproximadamente (Figura 9).

Estos casos teóricos y tabulares están destinados a darnos una idea sobre los valores que es posible encontrar en la región.

Las curvas se han reproducido en la figura N° 6 ; son comparables a las curvas teóricas que nos permitieron determinar las conductancias de las estaciones experimentales utilizadas en el mapa 5 y dadas en el anexo 2 por medio de curvas del anexo 3.

VI-7 DIRECCIONES PRINCIPALES

La dirección principal se ha presentado en el fascículo sobre la interpretación del M.T. (Anexo 1). Define la dirección de circulación preferencial de corrientes telúricas ; es perpendicular a la dirección de las variaciones más fuertes del campo magnético.

Estas direcciónes corresponden a menudo con las conductancias longitudinales mayóres y están relacionadas con la dirección de los accidentes, con la dirección de mayor pendiente de un monoclinal o con la dirección de fracturación.

Las direcciones siempre se pudieron calcular ya que ninguna estación era perfectamente tabular. También se pudieron calcular incluso cuando la cilindricidad de las estaciones era debil o nula.

Por el contrario, el cálculo demostró una indecisión respecto al signo (en relación a OX). En este caso y para mayor prudencia, la dirección no fue llevada al mapa.

Tres direcciones aparecen globalmente sobre el mapa :

a) <u>Una dirección Norte-Sur o casi Norte-Sur</u>.

Esta dirección se encuentra principalmente en las zonas Noreste y Norte (estaciones 64, 63, 65, 22, 20 y 17).

En esta zona, no se puede comparar con las direcciones deducidas de los mapas SOFREM. Es evidente que las direcciones nos ayudan mucho a dibujar el mapa de iso-conductancia y de resistividad vertical (5 y 6) que utilizan muy pocas estaciones.

Se encuentra esta dirección Norte-Sur en algunas estaciones de la Zona Intermedia al Oeste del pozo La-1 y al Sur de la Montaña del Fuego (estaciones 37 y 38). Esta dirección no está indicada en los mapas SOFREM.

Esta dirección también se encuentra al Sureste, en la estación aislada N° 58. Es probable que se trate de una dirección antigua y profunda.

b) Una dirección Noroeste/Sureste que aparece alrededor de la Montaña del Fuego (estaciones 73, 11, 49 y 40)en la Zona Intermedia del sondeo (estaciones 2 y 4).

Esta dirección no se encuentra en los resultados de los sondeos SOFREM dando variaciones brutales superficiales, salvo quizás el Norte de la Montaña del Fuego.

La misma dirección aparece todavía al Sur de la zona occidental (del Golfo) en las estaciones 55, 24 y 35.

Esta dirección también se puede considerar como relativamente antigua y profunda.

c) La dirección Este-Oeste se encuentra al Sur de la Zona Intermedia del sondeo (al sur de la Montaña del Fuego) al Norte de la Zona del Golfo (estaciones 26, 28, 31 y 29) y en una estación al sur de la Montaña del Fuego (75).

Esta dirección es la que puso en evidencia el SOFREM.

Parece corresponder a discontinuidades muy fuertes (fallas, fracturas, contactos verticales) entre sectores conductores y sectores más resistentes.

Este fenómeno, que se ha visto mediante el SOFREM, se sigue en las bajas frecuencias, por lo menos al Oeste (zona del Golfo) y en el borde sur de la Zona Intermedia (estación 6). No obstante no ha podido ser localizado en profundidad allí donde el SOFREM encontraba anomalías, al sur del sondeo y de la Montaña del Fuego (estaciones 3, 4, 5, 37 y 38).

d) La estación 52, que no es de buena calidad, indica una dirección que parece aberrante en este estudio (NE-SO), pero la densidad de las estaciones es demasiado baja para garantizar que no corresponde a un rasgo geológico.

VI-8 RESISTIVIDAD APARENTE VERTICAL

Las zonas de falla o de discontinuidad brutal pueden averiguarse por la relación $r = \rho aL/\rho aV$ o por la resistividad aparente vertical ρaV para una constante de tiempo dada (en este caso $\tau = 64$ S).

Midiendo los r en cada estación, encontramos que 28 estaciones son normales (sin campo Hz fuerte) y sin contraste elevado. Al contrario, 12 estaciones están muy contrastadas y podrían situarse cerca de un accidente importante. Son las estaciones 7, 9, 17, 26, 41, 45, 65, 73 y sobre todo las estaciones 20, 24, 30 y 31.

No se ha realizado mapa de τ ya que los accidentes observados son dificilmente prolongables teniendo en cuenta el gran espacio entre estaciones.

Se ha trazado el mapa de iso-resistividades aparentes verticales para $\tau = 64$ S (mapa N° 6). En este mapa, aparecen varias zonas con fuertes discontinuidades (que son igualmente las más conductoras).

Estas zonas son :

- en la estación 45 (se sabe que no es cilíndrica) al Este del estudio y la estación 65 al Norte.
- en la zona occidental del Golfo donde se conoce una dirección Este-Oeste. Esta zona recuerda las fuertes discontinuidades de superficie de ρ_a de los sondeos SOFREM pero desgraciadamente las estaciones de esta zona son de mediocre calidad.

No obstante es interesante notar que esta zona de debil resistividad vertical se prolonga hacia el Este al Norte de la Zona Intermedia (sector de sondeo) y al Sur de la Montaña del Fuego donde se ha encontrado una dirección Este-Oeste bien marcada (estación 75).

Este trazado, que indica una fuerte discontinuidad Este-Oeste, pasa por las estaciones : 30, 26, 9 y se dirige hacia la estación 75. Esta zona también se podía haber interpretado mejor con un mayor número de estaciones ya que el borde Norte de esta anomalía se desconoze por completo.

VI-9 CONDUCTANCIAS LONGITUDINALES APARENTES

VI-9-1 NOTAS GENERALES

Los valores de las conductancias longitudinales aparentes se dan en las listas de resultados (Anexo 2). Se han determinado a partir de curvas de resistividad aparente en funcion de $\sqrt{\tau}$ y han permitido dibujar el mapa N° 5.

Los modelos retenidos, casos 1, 2, 3 y 4, han mostrado los valores de conductancia a los que se podía llegar, entre 280 y 850 mhos en casos tabulares suponiendo que los depósitos de agua de mar son muy porosos y permeables. Es evidente que los valores un poco más fuertes podrian obtenerse aumentado aún más las hipótesis de temperatura profunda y de depósito superficial, pero no es probable para el caso de las coberteras conductoras ya que nunca se han observado en superficie (ya sea por el método Dipolo SOFREM o por los estudios geológicos de terreno).

Una incognita persiste en la capa geológica profunda, entre 2 600 m y el zócalo. No se conoce ni su estructura, ni las variaciones de espesor, ni su resistividad exacta.

Se puede notar simplemente que la hipótesis es próxima a la realidad ya que se han encontrado valores muy resistentes : 185 mhos en la estación 58, 225 mhos en la 17 y 210 mhos en la 22, que por otra parte son todas de calidad 3.

En estas condiciones, las estaciones representarían zonas sin ningún desarollo de almacen de agua.

Para estas 3 estaciones es importante saber si estos valores únicos se confirman por valores análogos alrededor, o si son anomalías muy localizadas y entonces quizás se deban a efectos tectónicos.

La estación 17 por ejemplo no es cilíndrica, puede estar cerca de un accidente y por ello no ser significativa.

Por el contrario las estaciones 22 y 58 son cilíndricas y de calidad aceptable, incluso si r (0,15) es lo bastante elevado en las dos estaciones (accidente cercano ?).

En lo que respecta a las estaciones muy conductoras, se puede suponer una invasión importante de agua de mar o una zona geotermal. Aqui el problema es el de la calidad. Ya hemos visto que cuando las estaciones son de calidad 4, no cilíndricas, próximas a un accidente y distantes entre ellas era imposible concluir definitivamente y por lo tanto también lo era implantar un sondeo de reconocimiento.

VI.9.2 Zona Noreste (al Este de la Caldera Blanca)

Ya se habló de esta zona mencionando la anomalía (quizás accidente) de la estación 45. Hay pocas medidas para confirmar la forma, dimensión y significado de esta anomalía. Si esta correctamente representada en el mapa interpretativo, podría tratarse ya sea de una zona fracturada en profundidad (aparentemente no es superficial, pero no se sabe ya que no había SOFREM), o de una anomalía de almacen. El valor obtenido se aproxima del valor encontrado en el pozo La.1 ; a priori no es una medida suficiente para que sea considerada como objetivo geotérmico.

VI.9.3 Zona Norte (al Oeste de la Caldera Blanca)

Esta zona está marcada por una dirección N-S que sería antigua y profunda pero de la cual se desconoce el significado.

En una zona globalmente resistente (ausencia de fracturación y de invasión) con la excepción de la anomalía Norte (estacion 65) que podría marcar una invasión por agua de mar (920 mhos).

Señalemos que la estacion 65 es de muy buena calidad y cilíndrica, la presencia de anomalía parece indicutible. No obstante nos encontramos próximos a un accidente (r = 0,19), y para mayor precisión habría que tener 3 o 4 estaciones más.

VI.9.4 Zona Occidental del Golfo

Esta zona también está muy influenciada por el mar.

La tendencia general de la zona, marcada por direcciones Este-Oeste con zonas muy conductoras (estaciones 26, 29 y 31) y zonas estrechas muy resistentes, recuerda los mapas ρ_a del SOFREM. La zona parece estar rodeada por un accidente Este-Oeste al Norte como ya se había señalado anteriormente.

Los valores obtenidos (superior a los 2 000 mhos) tienden a demostrar la presencia de un yacimiento geotérmico (caliente, salado, permeable y poroso a bastante profundidad).

No obstante, teniendo en cuenta la forma (que recuerda la de las anomalías SOFREM), se pueden ver fracturaciones relativamente estrechas, amplificando los valores de conductancia más allá del valor real.

Hay que señalar también que la calidad de las estaciones no es buena (sobre todo en las estaciones 31, 29, 26) y que algunas muestran la presencia de accidentes muy proximos (31, 30, 26, 41 e incluso la 28). Por lo tanto hay que ser prudentes.

Si el agua de mar invadiendo las series puede dificilmente explicar una gran anomalía conductora de 1 500 a 2 500 mhos, podría indicar alternancias de compartimentos de 300 a 900 mhos que, considerados sin precaución, darían precisamente anomalías fuertes, orientadas, cilíndricas y no indicarían la presencia de un yacimiento geotérmico.

La única posibilidad de estudiar esta zona, si interesase al explorador, sería aumentando el numero de estaciones para ver si realmente una zona conductora de 10 km2 y de conductancia superior a 1 000 mhos puede dibujarse con seguridad ; en otros términos, saber si el mapa actual puede confirmarse.

VI.9.5 Zona Intermedia del sondeo

Cerca del sondeo La 1, se ha encontrado una pequeña anomalía conductora de aproximadamente 800 mhos, por una estación de muy buena calidad y confirmada por 3 o 4 estaciones comparables de excelente calidad.

Nuestra explicación sería la presencia de un conjunto de almacenes (verificados por las pérdidas encontradas durante la perforación del sondeo) invadidas de agua salada y caliente del tipo de modelo (casos 2 - 4).

Los sondeos SOFREM muestran que los almacenes superficiales són irregulares, alineados en el sentido Est-Oeste y culminando hacia la profundidad de 200 m.

Las estaciones M.T. muestran que los almacenes más profundos pueden tener una dirección NO/SE, son muchos más resistentes, localizados y calidos.

La anomalía es demasiado pequeña para que corresponda a yacimientos geotérmicos.

Hacia el SE se desarolla un sector mucho más resistente (desaparición de la fracturación profunda) con igual dirección o de dirección Este-Oeste, pero con las mismas anomalías superficiales ya observadas por el SOFREM.

VI.9.6 <u>Zona de la Montaña del Fuego</u>

Como ya mencionamos, esta zona está mal estudiada :

- No hay suficientes estaciones de buena calidad.
- La distancia entre estaciones es demasiado grande.
- Las zonas termales no pudieron estudiarse a causa de un fenómeno físico.

Sin embargo parece que la conductancia es demasiado debil, del orden de 400 mhos, con una dirección Noroeste/Sureste.

Independientemente de las complicaciones debidas a la estructura (la estacion 11 no es cilíndrica) y a la mediocre calidad de las estaciones (la estación 11 es de calidad 4 y las estaciones 75 y 73 de calidad 3) semejante conductancia podría interpretarse de 2 maneras :

- <u>una debil invasión</u> de agua de mar, superior a la encontrada en las estaciones 58, 22 y 17, ligeramente inferior a la de las estaciones 37, 38 y 39, y muy inferior a la de la zona del sondeo.

- una zona seca sin agua de mar pero con rocas suficientemente calientes para que la conductancia aumente de manera significativa de 280 mhos (roca compacta fría) a 400 mhos (como en el modelo del caso 4).

Evidentemente esta última hipótesis es la que retenemos ya que tiene en cuenta los resultados geológicos y geoquímicos conocidos.

Señalemos al Este una estación conductora pero aislada, poco cilíndrica y de calidad 3 (estación 16). Si se hubieran realizado otras estaciones alrededor y que hubiesen confirmado una anomalía conductora en esta zona, hubiera sido muy interesante, porque de esta manera, tendríamos un sector próximo a la anomalía térmica, invadido por el agua y que pudiera presentar un interés económico siempre que el sector fuese grande, de buena calidad y con conductancias fuertes.

En este caso, sólo un estudio complementario afirmaría la hipótesis.

CONCLUSIONS

VII - CONCLUSIONES

The MT study has covered a large area (90 Km²) with only 40
El estudio M.T. qu cubre una vasta zona (90 km2) con solamente 40
acceptable stations ... it doesn't have a sufficient density
estaciones de calidad aceptable, no tiene una densidad suficiente
as for permitting a perfect solution
como para permitir soluciones perfectas.

Never theless we have the corresponding signals and divergencies between
Sin embargo hemos señalado las correspondencias y divergencias entre
the superficial geologic structure (rock resistances recorded by zone
la geología structural superficial (rocas resistentes recortadas
stretches of fracturation (E-O) and invasions of water in
por zonas estrechas de fracturacion (E-O) e invadidas de agua en
the base and the deep structure (N-S direction or NW/SE or including E-W)
la base) y la estructura profunda (direccion N-S o NO/SE o incluso
in this case, also with invasion zones by conducting waters
E-O)en este casó, también con zonas invadidas por aguas conductoras
without having discerned with certantity the presence of no geothermal
sin que se haya discernido con certitud la presencia de ningun yaci-
deposit
miento geotérmico.

About this theme, two worthy zones to turn over to be examined before
Sobre este tema, dos zonas merecerían volver a ser examinadas antes
concluding dibinitively: the zone of the Gulf to the West and the small
de concluir definitivamente : la zona del Golfo al Oeste y la pequeña
zone to the East of the Montaña del Fuego
zona al Este de la Montaña del Fuego.

The thermal zone of the Montaña del Fuego appears as a zone of sufficient
La zona termal de la Montana del Fuego aparece como una zona bastante
resistance (without reservoirs invalled of water) but not too much, this relative
resistente (sin almacen invadido de agua) pero no demasiado, esta
conductivity is probably related to a thermal phenomenal
conductividad relativa está probablemente ligada a un fenomeno térmico
reheating of a geologic series
(recalentamiento de la serie geologica).

The zone of the drill hole, moderately conductive, is able to explain by an
La zona del sondeo, moderadamente conductora, puede explicarse por una
invasion of sufficient saline water but in an insulated sector and is interesting
invasión de agua bastante salada pero en un sector aislado y sin interés
from the point of view of the geothermal exploration.
desde el punto de vista de la exploración geotérmica.

MINISTERIO DE INDUSTRIA Y ENERGIA

INSTITUTO GEOLOGICO Y MINERO DE ESPAÑA

Seesmic noise
150 points cover the area of the springs - 128 usable.
20 minutes
Pg 16, 17, 30

COMPAÑIA GENERAL DE SONDEOS, S.A.
MADRID, DICIEMBRE DE 1.979

ESTUDIO MICROSISMICO Y DE RUIDO SISMICO DE LA FOSA DEL VALLES (BARCELONA)

INTRODUCCION

Como fase prospectiva final al estudio geotérmico de la fosa del Vallés (Barcelona) antes de pasar a sondeos de reconocimiento, el INSTITUTO GEOLOGICO Y MINERO DE ESPAÑA encargó a la COMPAÑIA GENERAL DE SONDEOS la ejecución de una última campaña con métodos más sofisticados: magnetotelúrica, audiomagnetotelúrica, dipolos, microcísmica y análisis de gases.

Los métodos geofísicos se han puesto a punto ex profeso para este proyecto en colaboración con D. RAMON ORTIZ RAMIS, del Instituto de Geofísica del C.S.I.C., y son motivo de un informe aparte, al igual que los análisis de gases efectuados por el Prof. FRANCO TONANI.

Los estudios sismológicos se han dividido en dos apartados: un estudio del ruido sísmico de toda la fosa del Vallés, como una técnica más a superponer a todas las efectuadas para intentar detectar las anomalías geotérmicas; y en segundo lugar un estudio de terremotos cuya primera idea era intentar estudiar los mecanismos focales pero que no ha sido posible por falta de instrumentación y se ha suplido con la campaña de ruido sísmico antes referida.

En estos casos se ha contado con la ayuda del Instituto Geográfico Nacional, quien cedió un microsismógrafo de los de su red de observación nacional durante dos meses para este fin y con la cooperación de la Cátedra de Geofísica de la Facultad de Físicas de la Complutense, a quien pertenecen los geófonos empleados en el estudio, que se ha ocupado de la interpretación de los sismogramas obtenidos -

under the supervision of Chief of the
bajo la supervisión de D. AGUSTIN UDIAS, Jefe del Departa-
The demodulation of the tape of noise seismic have
mento. La demodulación de las cintas de ruido sísmico ha -
been again carried to at last in the reference professorship by
sido también llevada a cabo en la referida Cátedra por D.
RAMON ORTIZ.

The works of country and interpretation of the
Los trabajos de campo e interpretación de los re-
results of the noise seism have been carried to last
sultados del ruido sísmico han sido llevados a cabo por D.
in Sciences Geologic and
JOSE F. ALBERT BELTRAN, Dr. en Ciencias Geológicas y D. JOSE
COROMINAS BLANCH, Ldo. en Ciencias Geológicas de la COMPAÑIA
GENERAL DE SONDEOS, S.A.

MICROSISMICIDAD

2.1. OBJETIVOS DEL ESTUDIO.

One of the principal problems setting up in
Uno de los principales problemas planteados en -
the directly related with the anomalies
la fosa del Vallés, directamente relacionado con las anoma
geothermal in her existences defined (determined) good by the
lías geotérmicas en ella existentes, definidas bien por las
manifestations superficial good by the studies prospective
manifestaciones superficiales, bien por los estudios pros-
until now realized is ~~to~~ to determine the geometry
pectivos hasta ahora realizados, es determinar la geometría
and possible functions of the fractures that ~~it~~ it limits
y posible funcionamiento de las fracturas que la limitan.

The knowledge of the geometry of the planes of
El conocimiento de la geometría de los planos de
fault is essential to the hour of locating sound~~s~~ of
falla es imprescindible a la hora de emplazar sondeos de -
recognition of the anomalies studied in function of
reconocimiento de las anomalías estudiadas, en función de
the profoundity ~~to~~ that desire to cut out the zone ?
la profundidad a que se desee cortar la zona milonitizada
of the faults as horizondal potentially productive
de las fallas como horizontes potencialmente productivos.

to determine if the falts are active in ~~the~~ actuality
so Determinar si las fallas son activas en la actua
thus as the mechanims of its possible movement
lidad, así como los mecanismos de su posible movimiento, -
put inte to the hour of establishing a model genitic
puede interesar a la hora de establecer un modelo genético
of the anomalies studies that permit an interpretation
de las anomalías estudiadas que permita una interpretación
correct of the same
correcta de las mismas.

The study of the microseismology of the zone is
El estudio de la microsismicidad de la zona es -
in principle a form of approach the problem already that in
en principio una forma de abordar el problema, ya que, en
the assumed ~~of~~ that the faults ~~are~~ are active and by much
el supuesto de que las fallas sean activas, y por tanto ge
generating of seismic of the zone the registration of the same
neradoras de sismos de la zona, el registro de los mismos
throughout a period of weather sufficient mediating a number
durante un período de tiempo suficiente, mediante un núme-
adequate of microseismographs permit
ro adecuado de microsismógrafos permitiría:

To Consult the activities of the faults
a) Constatar la actividad de las fallas.
To Calculate epicenters and deep hypocenters
b) Calcular epicentros y profundidades hipocen-
trales.

To determine its mechanism
c) Determinar su mecanismo.
To define with a certain precision the geometry
d) Definir con una cierta precisión la geometría
of the plane of faults
del plano de falla.

POSSIBILITIES OF EXECUTION AND METHOD UTILIZATION
2.2. POSIBILIDADES DE EJECUCION Y METODO UTILIZADO.

The realization of the study landed of entered
La realización del estudio planteaba de entrada -
two problems of kinds different a first problem material
dos problemas de índole diferente, un primer problema mate
that it constitutes the minimum of four stations registers
rial que lo constituía el mínimo de cuatro estaciones regis
in ~~functioning~~ simultaneously essential for
tradoras en funcionamiento simultáneo, imprescindibles para
the calculation of hypocenters and a second problem of kinds
el cálculo de hipocentros,y un segundo problema de índole -
technical reference to the disregard, oversight of the micro-seismicity
técnica referente al desconocimiento de la microsismicidad
of the zone that indicate in the determination of
de la zona, que incidía en la determinación de:

location more adequate for the stations
- emplazamientos más adecuados para las estaciones
of ~~registers~~ readings
de registro.

amplification minimum necessary for obtaining some
- amplificación mínima necesaria para obtener unos
readings acceptable
registros aceptables.

level of noise of the zone and its possible effect on the
- nivel de ruido de la zona y su posible afección
registration of the microearthquakes local.
al registro de los microterremotos locales.

Respect to the first problem includes to say that in this
Respecto al primer problema cabe decir que en es
moment doesn't exist in the country four microseismograph
te momento no existían en el pais cuatro microsismógrafos
available position station that only there are the that integrate the
disponibles, puesto que solo hay los que integran la men-
decrease net of the and normally
guada red del Instituto Geográfico y Catastral y normal-
are utilized to full exhaustion by it that of
mente están utilizados a pleno rendimiento, por lo que de
surface of the execution of the study only left the resourt of
cara a la ejecución del estudio solo quedaba el recurso de
buying or making the aparatus necessary with the implications
comprar o fabricar los aparatos necesarios, con las impli-
economic that they bear or suffer together
caciones económicas que ello conllevaba.

Respect to the second problem is evident that only
Respecto al segundo problema es evidente que so
able to solve it practically is to say installed
lo podía solventarse prácticamente, es decir, instalando -
Stations of registration and analization of the results
estaciones de registro y analizando los resultados.

These problems, joined with the date of that in
Estos problemas, junto con el hecho de que en -
these momentos the had made use
estos momentos el Instituto Geográfico Nacional tenía dispo
of throughout one or two months an aparatus hanging pending of location, situation
nible durante uno o dos meses un aparato pendiente de ubica
to advise the installation of an only station of
ción, aconsejaron la instalación de una única estación de -
registration that permits a recognition of the zone and in
registro que permitiría un reconocimiento de la zona y en -
consequence validation the option of a second phase in the
consecuencia validaría la opción de una segunda fase en la
that already been able to install all the stations necessary
que ya podrían instalarse todas las estaciones necesarias.

CHARACTERISTICS OF THE STATION REGISTRATION

2.3. CARACTERISTICAS DE LA ESTACION REGISTRADORA.

The station installed is constituted by a
La estación instalada estaba constituida por un
microseismicgraphic yeild, as already have referred by the
microsismógrafo cedido, como ya se ha referido, por el Ins-
and a sensor of yeilding
tituto Geográfico Nacional, y un sensor de 1 Hz (Geotec) ce
by the
dido por la Cátedra de Geofísica de la Universidad Complu-
The installation carried to end in the cottage
tense de Madrid. La instalación se llevó a cabo en la case
of a station transformer situated in the away, outside of
ta de una estación transformadora situada en las afueras de
property of the
Rubí, propiedad de la Empresa Nacional Hidroeléctrica Riba
to loading of whose personal ran the mantainence
gorzana, a cargo de cuyo personal corrió el mantenimiento -
of the station through the two months and between that study in
de la estación durante los dos meses y medio que estuvo en
Function. The installation and setting to point of the same
funcionamiento. La instalación y puesta a punto de la mis-
sun to load of
ma corrió a cargo de D. RAMON ORTIZ RAMIS, Dr. en Ciencias
Físicas (Instituto de Geofísica del CSIC).

The emphasis of the station indicates in the
El emplazamiento de la estación se indica en el
map 1 and to scale regional in the fig. 1 To be left situated in
mapa 1, y a escala regional en la fig. 1. Queda ubicada en
the border SW of the depression, in a zone next to the
el borde SW de la depresión, en una zona próxima a la in-

Intersection of the fault southwith the transversal of the LLobregat
tersección de la falla sur con la transversal del LLobregat.
The event of that situated about the full ~~...~~ comes
El hecho de que se situara sobre el relleno arcósico vino -
duty tax by the availability of the ~~...~~ place + granted by
impuesto por la disponibilidad del lugar cedido por ENHER.
Although the placement was not optimum always to be conceted the
Aunque el emplazamiento no fuera óptimo, siempre cabría la
possibility of improving the registers to the improvement the placement
posibilidad de mejorar los registros al mejorar el emplaza
of the station
miento de la estación.

RESUTS OBTAINED
2.4. RESULTADOS OBTENIDOS.

The station stutted in functionally from the
La estación estuvo en funcionamiento desde el 18
January until the April 1 1980 obtained a total
de enero hasta el 1 de abril de 1980, obteniéndose un total
of results summarized in the attached The analysis of
de 73 registros recopilados en el Anexo 1. El análisis de -
the same has been effecting in the
los mismos ha sido efectuado en la Cátedra de Geofísica de
by
la Universidad Complutense de Madrid por D. MARIANO GARCIA
in Sciences Phical under the
FERNANDEZ, Ldo. en Ciencias Físicas, bajo la supervisión -
de D. AGUSTIN UDIAS, Catedrático de Geofísica.

In the Table I gathered those events observed
En la Tabla I se recogen los eventos observados,
indicated the following ~~...~~ facts about them:
indicando los siguientes datos sobre ellos:

Day Month and year
FECHA: Dia, mes y año.
Hour, minute, second and tenths of second of the primer
HORA: Hora, minuto, segundo y décimas de segundo del primer
impulse of the event In local time
impulso del evento. (En tiempo local).
Difference of time, in seconds, between the arrivals
S - P: Diferencia de tiempo, en segundos, entre las llega-
of the waves P and S Only in the events clearly
das de las ondas P y S. (Sólo en los eventos clara-
identified as earthquakes
mente identificados como terremotos).
Epicenter distance in Km
: Distancia epicentral en km.
Amplitude maximum measurement about the seismogram, in mm
A : Amplitud máxima medida sobre el sismograma, en mm.

OBSERVATIONS Indicate the type of event and in its case
OBSERVACIONES: Se indica el tipo de evento y en su caso, -

36 events

TABLA - I

Jan 18

FECHA	HORA	S-P		A	OBSERVACIONES
18-I-80	20 56				?
22-I-80	19 40 55				?
25-I-80	17 48				?
29-I-80	19 02 46.5	7	60	9	Terremoto
02-II-80	09 30				?
02-II-80	09 53				?
02-II-80	10 17				?
06-II-80	16 14				?
09-II-80	10 30				?
11-II-80	13 45				?
11-II-80	16 42				?
22-II-80	13 54				?
28-II-80	15 15				?
28-II-80	18 11				?
29-II-80	21 41 57.7			50	Terremoto principal
29-II-80	23 59 14	31	245	2	aftershock Réplica del 29-II-80
01-III-80	16 04 51.2	30	240	6	Réplica del 29-II-80
01-III-80	23 07 06.9	31	245	7	Réplica del 29-II-80
02-III-80	03 23 41.5	32	250	17	Réplica del 29-II-80
02-III-80	23 50 25.	30	240	1,5	Réplica del 29-II-80
03-III-80	01 37 21.5	33	255	33	Réplica del 29-II-80
04-III-80	05 40 38	32	250	5	Réplica del 29-II-80
05-III-80	09 08 53	33	255	8	Réplica del 29-II-80
10-III-80	18 46				?
11-III-80	15 16 43.9	21	170	17	Terremoto
11-III-80	14 28 21.2	0,75	10	6,5	Explosión
13-III-80	13 56				Posible terremoto tapado por el ruido.

.../...

TABLA - I (Continuación)

FECHA	HORA		S-P		A	OBSERVACIONES
14-III-80	14 20					?
14-III-80	14 39					?
18-III-80	02 20	40.5	30	240	3	Réplica del 29-II-80
19-III-80	14 10					?
19-III-80	21 15					?
24-III-80	05 13					?
24-III-80	09 10					?
26-III-80	21 57					?
29-III-80	23 38	18.2	13	115	11	Terremoto

Some other date of interest if write the symbol ? it
algún otro dato de interés. (Si se escribe el símbolo ? sig
signifies that we do not know the nature of the event, but it
nifica que no se conoce la naturaleza del evento, pero lo -
most probable is that treated of an earthquake
más probable es que no se trate de un terremoto).

Of the lecture of the Table 1 able to check
De la lectura de la Tabla 1 se puede comprobar -
the practice absence of events related with the seismicity
la práctica ausencia de eventos relacionados con la sismici
local it doesn't signify that no exists such type of seismology
dad local; ello no significa que no exista tal tipo de sis-
except that the small sensibility of the that encountered
micidad, sino que la baja sensibilidad a la que se encontra
regularly the machine properly to the top level of the noise exists
ba regulado el aparato, debido al alto nivel de ruido exis-
in the zone it is that it was imperceptible the signals
tente en la zona, hace que sean imperceptibles las señales
must to the microseismic locals or, in the major of the
debidas a los microsismos locales o, en el mejor de los ca-
cases, that still registered noise signals this stay concealed
sos, que aún registrando dichas señales, éstas queden ocul-
by the level of noise environmental
tas por el nivel de ruido ambiental.

In consequence only have registered with clarity
En consecuencia solo se han registrado con cla-
the earthquake principal of the of the region
ridad el terremoto principal del 29-II-80, de la región -
of the south of France and its replicas of major magnitude.
del sur de Francia, y sus réplicas de mayor magnitud.

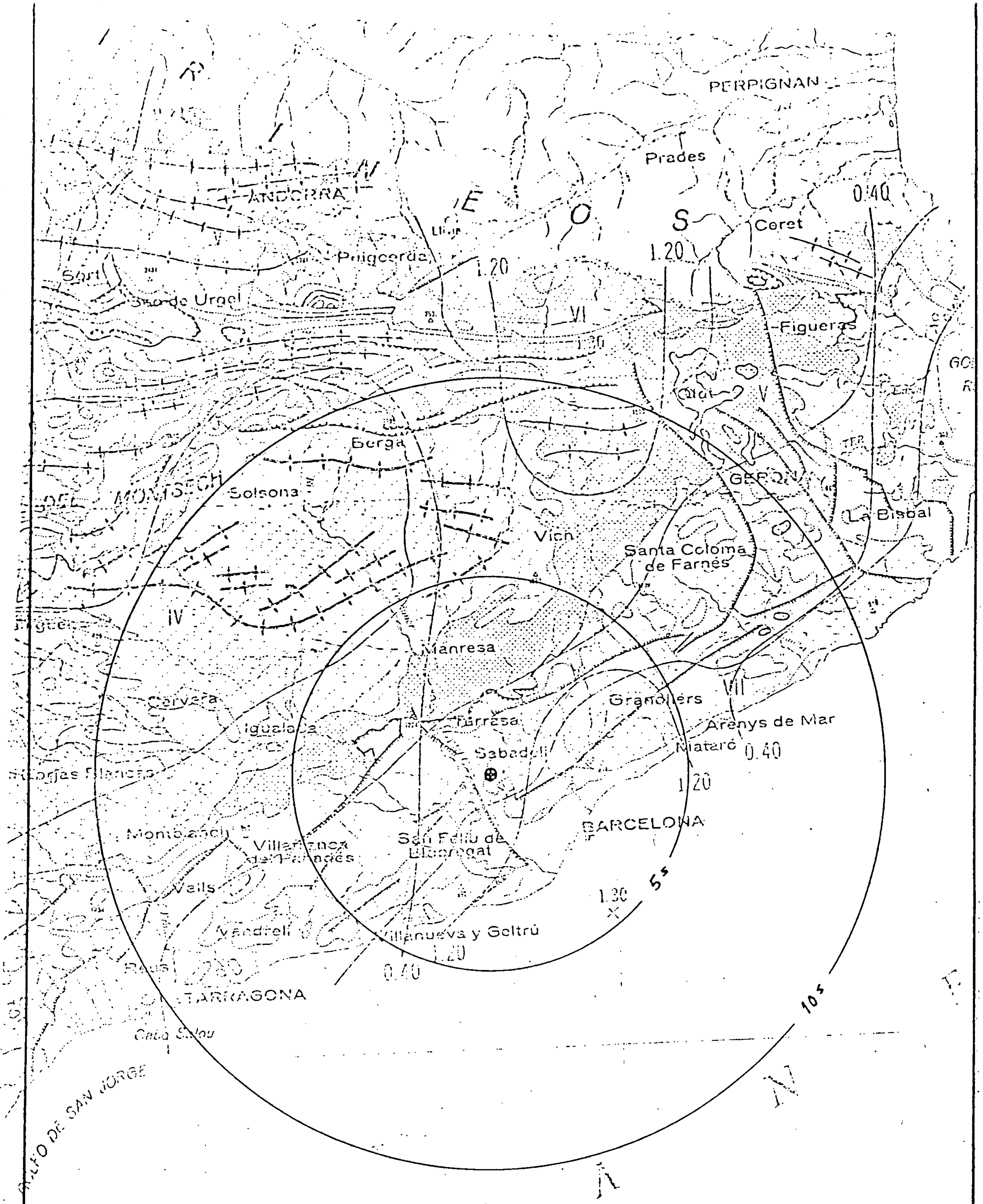
In the figure 1 have represented graphically
En la fig. 1 se han representado gráficamente,
about a map of the zone, the equal lines of differences
sobre un mapa de la zona, las isolíneas de diferencias S-P,
for visualizing the distances epicenters of the that
para visualizar las distancias epicentrales a las que co--
correspond
rresponden.

End of more complete translation

RECOMMENDATIONS

2.5. RECOMENDACIONES.

Viewing the results obtained in this campaign
Vistos los resultados obtenidos en esta campa-
preview of registers and the face of further studies of
ña previa de registros y de cara a ulteriores estudios de
microseismology applied to geometry duty to have in
microsismicidad aplicada a geotermia, deberían tenerse en
account the following details we must take into account
cuenta los siguientes detalles:



Escala 1:1.000.000

minimum amplif of 10^6

- La amplificación mínima necesaria para obtener unos registros aceptables sería en el Vallés del orden de 10^5, siendo un valor idóneo para sacar un rendimiento óptimo de los sismogramas, la amplificación de 10^6.

n.t.

need a quiet site away from communication routes & industry

site on crystalline rocks in horst to reduce attenuation

- Para conseguir estas amplificaciones es necesario tener cuidado en la elección del lugar de colocación del sismómetro; ha de ser, ambientalmente, un sitio tranquilo, lo más alejado posible de vias de comunicación y de zonas de trabajos de maquinaria, así como de líneas de conducción de electricidad de alta tensión. Es muy importante también, ubicar el registrador sobre afloramientos de materiales metamórficos o cristalinos (zona de horst), que permiten una excelente propagación de la señal con una absorción mínima.

For achieving these amplifications it is necessary to have attention in the selection of the place of position of the seismometer, environment a site quiet it is most involving possible of ways of communication and of zones of work of machinery thus as of lines of conduction of electricity of high tension. Is very important also to lie situated the station around outcrops of materials metamorphics crystalline ? that permit an excelent propagation of the signal with a minimum of absorbtion

locate a quiet site in preliminary survey.

- Antes de la instalación se debe hacer un reconocimiento instrumental de los posibles emplazamientos, con el fin de elegir aquel en que el nivel de ruido sea mínimo utilizando las amplificaciones consideradas como idóneas.

Before the installation it had to make a recognizable instrument of the possibilities of placing with the end of to choose there on that the level of noise is minimum utilized the amplifications consideration as qualified

4 sta. operating simultaneously for no less than 4 months.

El estudio de microsismicidad definitivo ha de llevarse a cabo con un mínimo de cuatro estaciones operando simultáneamente durante un tiempo no inferior a cuatro meses.

The study of micro seismology definitely has of carrying to end with a minimum of four stations operating simultaneously while a time does less to four months

relative cost/effectiveness of microearthquake survey would be very high!

No obstante, a pesar de todo lo expuesto, creemos que la relación coste/posibles resultados de un estudio de estas características sería extremadamente alta. Los re-

Nevertheless on the basis of this experience, we think that the relation cost/effectiveness results from a study of these characteristics are extremely high. The

results expects on the basis of this first taking of contacting
sultados esperables, en base a esta primera toma de contac-
with the problem we think that no justification in this zone
to con el problema, creemos que no justificarían en esta zo
a high cost that to suppose the sophisticated instrumentation
na el alto costo que supondría la sofisticada instrumenta--
and the time that is dedicated to the control daily of the
ción y el tiempo que se dedicaría al control diario de las
stations
estaciones.

s-o-a
use recording or
remote radio reporting

RUIDO SISMICO
(Seismic noise)

3.1. FUNDAMENTOS DEL METODO.

A través de los trabajos de diversos autores -(Clacy, 1968 y Douze and Sorrells, 1972, principalmente), - se ha establecido la existencia de un ruido sísmico asociado a la actividad geotérmica que puede contribuir a la formación del fondo regional o incluso llegar a ser predominante. Es en este caso, cuando la cuantificación del mismo mediante cualquier método prospectivo adecuado, permite detectar las anomalías geotérmicas que lo producen.

The origin of the seismic noise associated to activities
El origen del ruido sísmico asociado a activida-
geothermal is a fenomon not known very well, although it was
des geotérmicas es un fenómeno poco conocido, aunque se su-
able to but complete agree diverse causes in its origin, tales as
pone pueden concurrir diversas causas en su génesis, tales
como:

the movement of great volumes of water hot
- el movimiento de grandes volúmenes de agua ca
to diagonal of aquafers confined
liente a través de acuíferos confinados.

the movement of the water through the circulation
- el movimiento del agua durante la circulación
convection originate in the half semiconfined media / semi boundary
convectiva originada en los medios semiconfi-
by the continuous cooling and reheating
nados por el continuo enfriamiento y recalen-
of the same
tamiento de la misma.

the noise produced by the repeated changes
- el ruido producido por los repetidos cambios
of state between the distinct phases that integrate
de estado entre las distintas fases que inte-
the system liquid vapor dry vapor
gran el sistema: líquido -- vapor -- vapor se
vapor liquid
co -- vapor -- líquido.

Of made, the mechanisms genetic that originate
De hecho, los mecanismos genéticos que originan
the noise important relatively little and since a point of
el ruido importan relativamente poco y, desde un punto de
site prospective it important is the made of that a
vista prospectivo, lo importante es el hecho de que un cam

country geothermal puts generally a noise seismic susceptible of
po geotérmico pueda generar un ruido sísmico susceptible de
being captured in when able to utilize for the definition
ser captado, en cuanto puede ser utilizado para la defini-
of campo origin In this case the only problem that
ción del campo origen. En este caso el único problema que -
we seek is that the noise of origin geothermal or
se planteará es que el ruido de origen geotérmico supere o
is absorbed by the thoroughly regional exact to the resistance
sea absorbido por el fondo regional debido a las restantes
causes possibilities microearthquakes activities tropical? animals, etc.
causas posibles (microterremotos, actividad antrópica, ani-
in the first case, the use of the seismic noise as
males, etc); en el primer caso, el uso del ruido sísmico co
method of prospecting geothermal is valid and in the second
mo método de prospección geotérmica será válido y en el se-
case no.
gundo caso no.

poor spatial resolution of the method.

The study or the discussion of the mechanisms that
El estudio o la discusión de los mecanismos que
give origin to the noise in yes is interesting if it wants to insist
dan origen al ruido en sí es interesante si se quiere insis
on the capacity of resolution of the method prospective
tir en la capacidad de resolución del método prospectivo, -
it which in no case consists the conclusion of this study.
lo cual en ningún caso constituye la finalidad de este estu

dio.

END OF THE STUDY
3.2. FINALIDAD DEL ESTUDIO.

Givin the advanced state of the investigations
Dado el avanzado estado de las investigaciones -
geothermals in the depression of the Vallès with the existence
geotérmicas en la depresión del Vallés, con la existencia -
of a series of anomalies perfectly defined to through, across
de una serie de anomalías perfectamente definidas a través
of the manifestations superficial and of the methods prospective
de las manifestaciones superficiales y de los métodos pros
until now utilized hydrochemistry, geophysics and
pectivos hasta ahora utilizados (hidroquímica, geofísica y
thermometrics we decided to realize a study of the noise seismic
termometrías), se decidió realizar un estudio del ruido sís
of the zone as a chapter more on the scale prospective
mico de la zona como una etapa más en la escala prospecti-
to the same time that with them he was able to put a new
va, al mismo tiempo que con ello se ponía a punto un nuevo
method and contrast its validity
método y se contrastaba su validez.

test of seismic noise method in a known area of low temp. potential.

One event important to emphasize is that of the study
Un hecho importante a destacar es que del estu-
bibliographic — losten, detach that the method has been
dio bibliográfico se desprende que el método ha sido exclu

to date used only in high enthalpy systems!

exclusively applied to country geothermal of high enthalpy
sivamente aplicado a campos geotérmicos de alta entalpía, -
nevertheless not to be the methodically perfectly defined
sin embargo, al no estar la metodología perfectamente defi
and applied in the Vallés field, of local small enthalpy
nida y aplicarse en el Vallés (campo de baja entalpía) de -
deform compared and contrasted we think that the utilization
forma comparativa y de contraste, creemos que su utilización
was able to result interest as a technical more to superimpose
puede resultar interesante como una técnica más a superponer
the results already we know technique more to superimpose
a los resultados ya conocidos.

METHOD OF PROSPECTION
3.3. METODO DE PROSPECCION.

The studies of seismic noise enable us to realize
Los estudios de ruido sísmico pueden realizarse
three interceding methods of operation:
mediante tres métodos de operación:

Seismic recording and analysis in the laboratory
- Registro sísmico y análisis en laboratorio.
Analize the spectra in real time
- Analizador de espectros en tiempo real.
Simultaneous seismic recording and interceding analysis
- Registro sísmico simultáneo y análisis median
crusade convolution
te convolución cruzada.

The first method permited to obtain the maximum
El primer método permite obtener los máximos ren
efficiency, position that needs scaling twenty minutes
dimientos, puesto que se precisan escasamente veinte minu-
of recording by point
tos de registro por punto.

In the second method of obtaining the contents
En el segundo método se obtiene el contenido es
spectrum directly in the field that makes to diminish considerably
pectral directamente en campo lo que hace disminuir consi-
the number of points by day although it permits in
derablemente el número de puntos por día aunque permite en
all moments to have control over the recording
todo momento tener control sobre el registro.

The third possibility is, since a point of sight
La tercera posibilidad es, desde un punto de vis
theoretic view, the most advanced, position that permits us to utilize the
ta teórico, la más avanzada, puesto que permite utilizar el
most complete numerical treatment. For those its duty is to prepare
tratamiento numérico más complejo. Para ello se debe dispo
of a minimum of 3 to 5 stations synchronized
ner de un mínimo de tres o cinco estaciones sincronizadas
higher than 0.05 s. regularly displaced around of the
mejor que 0.05 s., dispuestas regularmente alrededor de la
to better than

zone of study, registered simultaneously during various
zona de estudio, registrando simultáneamente durante varias
hours. The results are appreciably better than limited to
horas. Los resultados son apreciablemente mejores aunque li
a very small area, that making an
mitados a una superficie muy pequeña, lo que hace que la a-
application of great extentions prohibitive, in as much
plicación a grandes extensiones sea prohibitiva, en cuanto
as economics refer.
a economía se refiere.

In the zone of study the first method has being utilized
En la zona estudiada se ha utilizado el primer -
since the report was conceived as general recognition
método ya que la campaña se concibió como de reconocimiento
and by his optimistic yield was primordial.
general y por ello optimizar el rendimiento fue primordial.
For his planning a mesh of 150 points of observation
Para ello se planificó una malla de 150 puntos de registro
which cover the entire area, of the springs 128 have
que cubría la totalidad de la zona, de los cuales 128 han -
useable results. These situation is given in map 2.
resultado utilizables. Su situación se da en el Mapa 2.
stations are

INSTRUMENTAL AND METHOD OF ANALYSIS.

3.4. INSTRUMENTAL Y METODO DE ANALISIS.

For the obtaining of data in field the location
Para la obtención de datos en campo se dispuso -
of two stations of seismic noise recorders on magnetic tape
de dos estaciones de registro sísmico en cinta magnética -
of the type utilized within the International Geodynamic
del tipo utilizado dentro del Proyecto Geodinámico Interna
Project, equipped with vertical component sensors of 2 Hz (Mark 2-4) and
cional, equipadas con sensores de componente vertical de 2
1 Hz (Geotec).
Hz (Mark 2-4) y 1 Hz (Geotec).

The laboratory analysis using interceding analysis
El análisis en laboratorio se realizó mediante
of analogic spectrums of 32 channels with moniter
analizador de espectros analógico de 32 canales con moni--
of cathode rays and leaving directly to register graphically
tor de rayos catódicos y salida directa a registrador grá-
fico.

In fig. 2 the diagrams presented blocks of
En la fig. 2 se presentan los diagramas bloque
the equipment and in table 2 the frequencies of calibrations
de los equipos y en la tabla 2 las frecuencias de calibra-
of the canals of the analizer.
ción de los canales del analizador.

registering a field for 20 minutes by
Se registro un campo durante veinte minutos por
point, repeating those points that the operator considered
puntó, repitiéndose aquellos puntos en los que el operador
unreliable, registering a total
consideraba haber detectado perturbaciones, registrándose
of 150 points
un total de 150 puntos.

In the process of laboratory demodulation
En el proceso de demodulación en laboratorio se
repelling a quantity of aproximately twenty points, by
rechazaron una veintena de puntos aproximadamente, por pro
problems of pulling in the magnetophone, possible saturation or
blemas de arrastre en el magnetófono, posible saturación o
insufficient level in the signal of entrance. Of the rest have
nivel insuficiente en la señal de entrada. Del resto se han
obtained the corresponding spectrums repeated there that
obtenido los correspondientes espectros repitiéndose aque-
do not present a good coherence to the long
llos que no presentaban una buena coherencia a lo largo de
period of registration. In the attached 2 have recopied
todo el período de registro. En el Anexo 2 se han recopila
all the spectros obtained.
do todos los espectros obtenidos.

For the interpretation they have grouped the
Para la interpretación se han agrupado las fre-
frequencies in five central bands in and
cuencias en cinco bandas centradas en 1 - 2 - 4 - 8 y 16 Hz
measuring the maximum amplitudes in each point.
midiéndose las amplitudes de sus máximos en cada punto.

RESULTS OBTAINED
3.5. RESULTADOS OBTENIDOS.

The maximum amplitudes in each point for the
Las máximas amplitudes en cada punto para las -
5 bands of frequencies in which we have divided the spectrum
cinco bandas de frecuencias en que se ha dividido el espec
are summarized in Table 3
tro se resumen en la Tabla 3.

To effect the visualization these results have been
A efectos de visualizar estos resultados se ha
elaborated a map of equal amplitudes for each band of frequencies
elaborado un mapa de isoamplitudes para cada banda de fre-
Maps 3 to 7 and at the same time have realized
cuencias (Mapas 3 al 7) y al mismo tiempo se ha realizado
an analysis statistico of the same figures 3 to 12 with
un análisis estadístico de las mismas (figuras 3 a 12) con
the end of defining the values anomalies within each band
el fin de definir los valores anómalos dentro de cada ban-
according to a distribution log-normal that patented in
da, según una distribución log-normal que se patentiza en

the corresponding histograms in them rests good patent
los correspondientes histogramas. En ellos queda bien paten
that within each band coexists by it less two families
te que dentro de cada banda coexisten por lo menos dos fami
distinct of values event that rests corroborating in
lias distintas de valores, hecho que queda corroborado en -
the corresponding graphs accumulated One of them
las correspondientes gráficas acumulativas. Una de ellas en
includes the values of minor intensity (that are greatest) giving
globa los valores de menor intensidad (que son mayoría), dan
a correlation log-normal generally good while
do una correlación log-normal generalmente buena, mientras
the second comprise values but in number much more reduced
la segunda engloba valores punta en número mucho más reduci
and with a correlation more irregular for the band of 1 Hz
do y con una correlación más irregular. Para la banda de 1
this second group of values practically don't stand out
Hz, este segundo grupo de valores prácticamente no se dibu-
this second group of values in practicality does not stand out. draw
ja.

I was failed to recognize totally the significance of the
Se desconoce totalmente el significado de los -
two groups given the great truth of fact that the were able
dos grupos, dada la gran variedad de factores que pueden con
to agree in its genisis especially of type ? since
currir en su génesis, especialmente de tipo antrópico, pues
that the zone in question has been situated next to a large
to que la zona en cuestión se halla situada junto una gran
city (Barcelona) and in which placed an important belt
urbe (Barcelona) y en ella se asienta un importante cintu-
industrial and urban
rón industrial y urbano (Rubí-Terrasa-Sabadell-Granollers),
besides of present a notable expanding agriculture and to be
además de presentar un notable desarrollo agrícola, y estar
crusade by a great number of ways of communication of elevated
cruzada por un gran número de vías de comunicación de eleva
transit
do tránsito.

The maps of equal amplitude have supposed
A los mapas de isoamplitudes se les ha supuesto
in color the representation of the zones anomalies calculated
en color la representación de las zonas anómalas calculadas
for the family more numerous that by minor intensity
para la familia más numerosa, que por su menor intensidad -
suppose was able to include the possibilities noise of origin geothermal.
se supone podría englobar los posibles ruidos de origen geo
térmico.

By the distribution of the anomalies we suppose
Por la distribución de las anomalías se supone
that the noise registered in the zone is principally of origin
que el ruido registrado en la zona es principalmente de ori
anisotropic (de origin ...) which all the maps present a
gen antrópico, puesto que todos los mapas presentan unos -
maxima which coincides with the ribbon of urban-industrial
máximos que coinciden con el cinturón urbano-industrial de

zone central southern
Rubí-Terrassa-Sabadell-Granollers (zona centro-meridional
of the depression especially in the bands of 4, 8 + 16 Hz
de la depresión), especialmente en las bandas de 4, 8 y 16 Hz.

All the maps shows a zone anomaly
En todos los mapas se manifiesta una zona anóma
in the sector east of the depression
la en el sector este de la depresión (Sn. Celoni - Breda)
than are not able to justify by an activity urban-industrial
que no puede justificarse por una actividad urbano-indus
important, already that the zone is relatively tranquil
trial importante, ya que la zona es relativamente tranqui-
especially in the foothills of Montseny border north
la, especialmente en las faldas del Montseny (borde norte
of the pit where they have registered values generally
de la fosa) donde se han registrado valores generalmente -
superior to the middle
superiores a la media.

Zone of non cultural noise

The anomalies geothermal defined in the zone through
Las anomalías geotérmicas definidas en la zona a
the other middle prospective no reflect clearly
través de otros medios prospectivos no se reflejan claramen
in none of the maps traces thus, of the three principal
te en ninguno de los mapas trazados. Así, de las tres prin-
anomalies geothermal known the
cipales anomalías geotérmicas conocidas, la de Papiol (sec-
remain comprised in case of existence within the
tor SW) queda englobada, en caso de existir, dentro de la -
strong anomaly of noise centered in Rubi, while the anomalies
fuerte anomalía de ruido centrada en Rubí, mientras las ano
of Caldes of Montbui and La Garriga - Samalus do not present
malías de Caldes de Montbui y La Garriga-Samalús no presen-
no noise anomaly or good give values only slightly ?
tan ningún ruido anómalo o bien dan valores solo ligeramen-
superior to the middle especially in the band of 4 Hz.
te superiores a la media, especialmente en la banda de 4 Hz.
The remainder of the anomalies conocide were able to stay perfectly
Las restantes anomalías conocidas podrían quedar perfecta-
spread within the background of noise anomalies
mente difuminadas dentro del fondo de ruido anómalo.

Evaluation of the Results
3.6. VALORACION DE LOS RESULTADOS.

Views in lines general the results obtained
Vistos, en líneas generales, los resultados ob-
were able to conclude that if existing in the depression of the Valles
tenidos puede concluirse que de existir en la depresión -
a noise of origin geothermal, this remains totally
del Vallés un ruido de origen geotérmico, este queda total
absorbed by the background local of manner that the prospect
mente absorbido por el fondo local, de manera que la pros-
geothermal by seismic noise no viable results
pección geotérmica por ruido sísmico no resulta viable.

geothermal anomalies were overcome by local & background noise in city areas - no viable results

Perhaps, of having planned a campaign of
Quizás, de haber planificado una campaña de re-
registers made use of the hours more tranquil of the night
gistros aprovechando las horas más tranquilas de la noche,
they had improved the results Nevertheless, the difficulty
se hubieran mejorado los resultados. Sin embargo, la difi-
in mobilizing and situating the stations united with the
cultad en movilizar y situar las estaciones junto con el -
little time available 4-5 hours per day realizing calm
poco tiempo disponible (4-5 horas/día realmente tranquilas),
that have provided a strong determination in the fatigue
que hubieran provocado un fuerte detrimento en el rendimien
daily and in consecutive a substantial increase
to diario y en consecuencia un sustancial encarecimiento -
of the project, it ?? Furthermore, views the characteristics
del proyecto, lo desaconsejaron. Además, vistas las carac-
of the zone at heart ? debt + high still
terísticas de la zona, el fondo antrópico debe ser alto aún
in hours tranquil of daybreak and failed to look until that
en horas tranquilas de madrugada y se desconoce hasta que -
point was able to deflect the audition of the noises properly
punto podría deficultar la audición de los ruidos propiamen
geologic
te geológicos.

To establish the conditions optimum of registering
Establecer las condiciones óptimas de registro -
needed in this zone some trials previous whose cost does not
requeriría en esta zona unos ensayos previos cuyo coste no
compensate the possible results that they were able to obtain,
compensaría los posibles resultados que podrían obtenerse,
it as disapproved this method of prospecting for the zone in
lo cual desautoriza este método prospectivo para la zona en
question
cuestión.

Thus in consequence, the methods of
Se desaconsejan, en consecuencia, los métodos de
geothermal prospecting by seismic noise
prospección geotérmica por sismicidad (micosismicidad y rui
in area of Vallés with strong influence
do sísmico) en zonas como el Vallés, con fuerte infuencia -
misleading
antrópica.

GEOREF NOTES

Cost: $84/hr CPU time
$8/hr connect time
30¢ / item for print-out listing

PRINTOUT: MARRIOT LIBRARY - dot matrix printer of fair quality. 1200 baud rate phone link

CALIFORNIA COMPUTER CENTER. - better quality printout but up to 8 days for delivery. Express mail service can be specified with an additional charge of $35.

SEARCHER: Ruth Frear is the most experienced 'searcher' for georef. 581-7702

THESAURUS: A georef thesaurus is available from the main desk of the Science & Eng. Library, 1st level, Marriott Library. This is a definite help when determining the key words for the search.

SEARCH LOGIC TYPES: AND, OR, NOT. References are searched for the union of key words, ie

Geothermal Energy
Geophysical surveys
Exploration
NOT GEOPRESSURE

should provide listing of references for geophysical methods for the exploration of geothermal resources, excluding geopressured resources.

COMPUTER AIDED SEARCH Rm 314 Marriott Library
581-7702

EXAMPLE SEARCH

```
File89:GEOREF - 29-84/Oct
(Copr. American Geological Institute)
          Set Items Description
          --- ----- -----------
            1  6596 GEOTHERMAL ENERGY
            2 43722 GEOPHYSICAL SURVEYS
            3  1207  1 AND 2
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* # of listings

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? ss s3 and py=1968:py=1984
```

4751865 PY=1968:PY=1984
5 1152 3 AND 4

? ss s5 and spain
6 8369 SPAIN
7 2 5 AND 6

? t 7/5/1-2
7/5/1
1027389 81-16997

Etude geothermique preliminaire du NE espagnol
A preliminary geothermal study of northeastern Spain
Albert-Beltran, J. F.

Proceedings of the International congress on thermal waters, geothermal energy and vulcanism of the Mediterranean area; geothermal energy; Volume 1
Augustithis, S. S.(president)
International congress on thermal waters, geothermal energy and vulcanism of the Mediterranean area; geothermal energy, Athens, Greece, Oct. 1976
Publ: Natl. Tech. Univ.
17-28p., 1976
9 REFS.
Subfile: B
Country of Publ.: Greece
Doc Type: BOOK; CONFERENCE PUBLICATION Bibliographic Level: ANALYTIC
Languages: French
tables
Latitude: N403000; N423000 Longitude: E0033000; E0000000
Descriptors: *Spain ; hydrogeology; economic geology ; thermal waters; geothermal energy; Europe; genesis; seismicity; epicenters; Pyrenees; Maladeta Massif; granodiorite; granite-granodiorite family; Andorra Massif; intrusions; Pliocene; Neogene; Tertiary; Cenozoic; volcanism; volcanology; geochemistry; chemical composition; albite-anorthite system; ion exchange; geothermal gradient; heat flow; geophysical surveys; Catalonia; electrical logging; well-logging; Gerona; tectonics; regional patterns; fracture zones; faults; exploration; areal geology
Section Headings: 21 (HYDROGEOLOGY AND HYDROLOGY)

7/5/2
540307 71-10207-G

HEAT TRANSFER MEASUREMENT IN A GEOTHERMAL AREA, IN GEOTHERMAL PROBLEMS - SYMPOSIUM, MADRID, SPAIN, 1969, PROC.
YUHARA, KOZO.
TECTONOPHYSICS, V. 10, NOS. 1-3 (SPEC. ISSUE), P. 19-30 1970
Subfile: G
Descriptors: *GEOPHYSICAL SURVEYS; *GEOTHERMAL AREAS; *GEOTHERMAL ENERGY; *HEAT FLOW; *HEAT TRANSFER MEASUREMENTS; *JAPAN

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? ds
Set Items Description
  1  6596 GEOTHERMAL ENERGY
  2 43722 GEOPHYSICAL SURVEYS
  3  1207  1 AND 2
  4751865 PY=1968:PY=1984
  5  1152  3 AND 4
  6  8369 SPAIN
  7     2  5 AND 6

? ss s5 and exploration
           8 55313 EXPLORATION
           9   556  5 AND 8

? t 9/5/1   7/1-2
9/7/1
 1252375   84-45042
```

Depositional setting, structural style, and sandstone distribution in three geopressured geothermal areas, Texas Gulf Coast
Winker, C. D.; Morton, R. A.; Ewing, T. E.; Garcia, D. D.
Report of Investigations - Texas, University, Bureau of Economic Geology i34, 60p., 1983
CODEN: TUGRAO ISSN: 0082-335X 26 REFS.
Subfile: B
Country of Publ.: United States
Doc Type: SERIAL Bibliographic Level: MONOGRAPHIC
Languages: English
Note: Assisted by Chong, L. P.; Han, J. H.; Lawton, J. L.; Padilla y Sanchez, R. J.; Palmer, J. J. and Rasco, R. D., illus., sects., strat. cols., charts, geol. sketch maps

```
9/7/2
 1251353   84-44617
```

Current geophysical exploration on Taiwan
Fujiwara, C.
Butsuri-Tanko 37: 2, 34-38p., 1984
CODEN: BTANAF ISSN: 0521-9191
Subfile: B
Country of Publ.: Japan
Doc Type: SERIAL Bibliographic Level: ANALYTIC
Languages: Japanese
illus., 5 tables, sketch map

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? ds
Set Items Description
  1  6596 GEOTHERMAL ENERGY
  2 43722 GEOPHYSICAL SURVEYS
  3  1207  1 AND 2
  4751865 PY=1968:PY=1984
  5  1152  3 AND 4
  6  8369 SPAIN
  7     2  5 AND 6
  8 55313 EXPLORATION
  9   556  5 AND 8

? ss s9 not gep opressure

          10   748 GEOPRESSURE
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? t 11/5/1-2
11/5/1
1251353 84-44617

Current geophysical exploration on Taiwan
Fujimara, C.
Butsuri-Tanko 37: 2, 34-38p., 1984
CODEN: BTANAF ISSN: 0521-9191
Subfile: B
Country of Publ.: Japan
Doc Type: SERIAL Bibliographic Level: ANALYTIC
Languages: Japanese
illus., 5 tables, sketch map
Descriptors: *Taiwan ; geophysical surveys; economic geology ; surveys ; geothermal energy; mineral resources; Asia; reserves; chemical composition; Tatun geothermal area; Chingshui; Lushan geothermal area; Tuchang-Chingshui geothermal area; Chipen geothermal area; hot springs; thermal waters; production; metal ores; nonmetal deposits
Section Headings: 26 .(ECONOMIC GEOLOGY, GENERAL & MINING)

11/5/2
1250709 84-45082

Geothermal study of Reunion Island; audiomagnetotelluric survey
Benderitter, Y.; Gerard, A.
Cent. Natl. Rech. Sci., Cent. Rech. Geophys., Pouilly sur Loire, FRA; Bur. Rech. Geol. et Miniere, FRA
Journal of Volcanology and Geothermal Research 20: 3-4, 311-332p., 1984
CODEN: JVGRDQ ISSN: 0377-0273 14 REFS.
Subfile: B
Country of Publ.: Netherlands
Doc Type: SERIAL Bibliographic Level: ANALYTIC
Languages: English
illus., sects., sketch maps
In 1979 and 1980, 535 magnetotelluric soundings using a frequency range of 1700 Hz-8 Hz were performed on the island of Reunion for geothermal exploration. Favorable geological conditions for this method were encountered and the results, which were controlled using classical electrical methods on test areas, suggest an unusual distribution of resistivities for lava flows situated above suspected geothermal areas. These layeres progressively decrease in resistivity down to a very conductive layer. In areas where these conductive layers were nearest the surface, detailed studies were carried out showing a close correlation between decreasing resistivity and increasing hydrothermal alteration. In addition, gradient wells reveal high geothermal gradients in such areas. The conductive layers revealed by audiomagnetotelluric soundings seem to correlate with thermal effects creating progressive hydrothermal alteration from an inferred hot-water reservoir up toward the surface.--Modified journal abstract.
Descriptors: *Reunion ; geophysical surveys; economic geology ; magnetotelluric surveys; geothermal energy; Indian Ocean; exploration; audiomagnetotelluric surveys; hydrothermal alteration; metasomatism; conductive materials; resistivity; interpretation
Section Headings: 29 .(ECONOMIC GEOLOGY, ENERGY SOURCES)

? ds

LOCATING DOCUMENTS FROM THE PRINTOUT

The information is retrieved from national/international databases via computer systems located in other states. The library collection may not contain the document for every citation listed on your printout. If the needed documents cannot be located in the U. of U. Libraries system (consult the Public Serials List or the Card Catalog), ask for assistance at the General Reference Desk. Consult the Interlibrary Loans (ILL) office, Room 310, Marriott Library for assistance in locating items not contained in the U. of U. Libraries system. (See Library Guide 3-3:ILL)

THE COST

The Library charges a fee for computer-aided bibliographic searches. The cost is based on the per-hour rate of the database (each database supplier charges a different rate). You are charged only for the actual length of computer connect-time (much like long distance telephone call charges) and the number of offline citations printed. Search cost vary widely, depending upon the complexity of the search, number of databases searched, and the amount of information/number of references retrieved. An average search costs between $10 and $20. The cost is considered by many to be small considering the hours, days, sometimes weeks saved over manual literature searching.

PAYMENT FOR A SEARCH

Payment for the computer search is on a cash/check basis at the conclusion of the search appointment. On-campus departments may use signed Campus Orders. Off-campus businesses/organizations may be billed ($5 service charge) with Purchase Order.

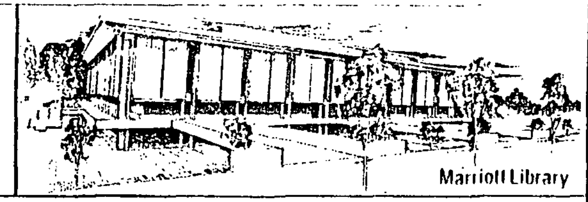
HOW TO SCHEDULE A SEARCH

Visit the C.A.R.S. office in Room 314 of the Marriott Library or call 581-7702. General information is available at the General Reference Desk. Stop in Room 314 for an interview or search appointment. Search request forms are available in Room 314 or at the General Reference Desk (3rd level).

HOURS

8:30 a.m. to 5:00 p.m. Monday-Friday. Other times may be arranged in advance.

University of Utah Libraries



COMPUTER-AIDED REFERENCE SERVICES

LEVEL THREE — LIBRARY GUIDE 3–12 — 581–7702

WHEN A FAST COMPUTER SEARCH CAN HELP:

Is your research paper deadline approaching and you don't have a list of references?
Are you writing a thesis or dissertation proposal and you need to know if someone else has researched your topic?
Would you like an easy way to stay current with the literature in your field?
Do you need a reading list for your class or seminar?
Do you need information on foundations and agencies which provide grant money or government funded research?

THE SERVICE

If the answer to these or similar questions is "yes", the Marriott Library COMPUTER-AIDED REFERENCE SERVICES (C.A.R.S.) may be what you want. Anyone needing a bibliographic search for a current research topic has immediate access through the library computer terminal to almost 200 databases covering most subject areas. Many of the databases available correspond directly to the printed index/abstracting services (e.g., Psychological Abstracts, E.R.I.C., Engineering Index, Chemical Abstracts, etc.).

Some of the databases are unique and are not available in print form (e.g., Economics Abstracts, International Conference Papers Index, Patent databases, Abstracted Business Information/INFORM, etc.)

Also available on many databases are current awareness searches, which are automatic monthly updates on your specific topic and which eliminate the need for you to search the literature manually.

The service is available to all University personnel--students, faculty, and staff--as well as to the general public, business, and government.

ADVANTAGES OF COMPUTER SEARCHING

Although it does cost money, a computer search can be an efficient and effective use of your valuable time as compared to spending many hours using manual methods.

A computer search can scan, in a matter of seconds, many years of an index or abstract.

The computer-produced bibliography can be tailor made to your special needs and interests (e.g., specific details, age groups, dates, geographic places, authors, etc.).

With a computer search, you can review a long list of citations rapidly and avoid writing down detailed bibliographic information.

It can supplement a manual search already completed and can also find references that can't be found in any other way.

The computer makes possible a more thorough search of your topic, with many more interrelated concepts, than could ever be accomplished by manual methods.

AVAILABLE DATABASE SUBJECT AREAS

Most major subject areas are covered by computer-searchable databases. These include the areas of business, economics, finance, and government; education, medicine, and psychology; physical and life sciences, social sciences, patents, technology, and sports. Some of the arts and humanities areas are also available.

A complete list of available databases, prices, and coverage years can be picked up at the C.A.R.S. office, Room 314, Marriott Library or at the General Reference Desk (3rd level). Most of the major abstracts and indexes in the Library and many not found in the Library, are searchable by computer.

HOW IT WORKS

The Marriott Library C. A. R. S. office is located in Room 314, near the General Reference Desk (3rd level). An information specialist will interview you to determine the best approach to your literature search and which databases best meet your needs. An appointment, usually for 1 hour, will be scheduled for the actual search at the computer terminal.

A brief manual search of the topic, by the patron, is encouraged prior to the actual search appointment. This enables the patron to be better prepared with relevant information about the topic and saves time and money during the computer search.

During the search interview, the patron will be asked to provide a description of the search topic with the terms or key words that might be used. The information specialist and patron will discuss the search and formulate a strategy. The search is performed with the patron present so that decisions relevant to the search topic can be made. Search time varies but connect time (for which the patron is charged) averages from 10 to 20 minutes. Total time involved for preparation, the search, and explanation of the results takes about an hour.

The online search process (directly connecting to and interacting with the computer) enables you to determine immediately the relevance of your search strategy and to make necessary changes to improve the results.

The references (author, title, source, etc.) can be obtained immediately at the terminal or ordered "offline" to be sent to the library within a week.

RESULTS FROM A COMPUTER SEARCH

The computer search generates a printed list of bibliographic citations to the literature written about a particular subject. Although the major type of material indexed is periodical literature, some books, dissertations, unpublished papers, reports, government documents, AV materials, pamphlets, etc. may also be included. Each item on the computer printout contains a full citation reference (author, title, source, etc.) and is used to <u>locate</u> the full text of the printed material. Many databases include an abstract (a brief summary sentence or paragraph) for each cited item.

COMPUTER-SEARCHABLE

DATABASES IN THE

PHYSICAL AND LIFE SCIENCES

AND ENGINEERING

AVAILABLE
AT THE
MARRIOTT LIBRARY
UNIVERSITY OF UTAH

Revised September 1984
Ruth A. Frear

SUBJECT AREA CONTENTS

The following is a list of science and engineering databases available for online searching in the Marriott Library. The databases are arranged alphabetically by title under broad subject categories.

Five vendors supply these databases to the Marriott Library: Bibliographic Retrieval Services (BRS), DIALOG Information Services (DIS), Institute for Scientific Information (ISI), Pergamon Info Line (PIL), and System Development Corporation (SDC). For further information about any of these databases or about online searching, call the Marriott Library's Computer-Aided Reference Services (CARS) office: 581-3886.

* Asterisk denotes databases which include patents.

MULTIDISCIPLINARY

ACADEMIC AMERICAN ENCYCLOPEDIA, current edition, biennial updates.
BRS, DIS (180)

This database offers full text coverage of some 29,000 articles appearing in the Academic American Encyclopedia, including the titles and texts of entries, tables, factboxes, bibliographies, cross references, pronunciation guides, and "see also" references. The AAE is a general encyclopedia covering all disciplines.

AMERICAN MEN AND WOMEN OF SCIENCE, 1979-present, updates every 3 years.
BRS, DIS (236)

The online equivalent of the printed reference work of the same title, this database provides names, addresses, and detailed biographical information on more than 130,500 preeminent U.S. and Canadian scientists. Included are personal statistics, education, experience, honors and awards, memberships, research interests, discipline, classification, and mailing address.

ASI, 1972-present, monthly updates.
SDC

Based on the printed American Statistics Index, this file covers statistical publications of the U.S. Government. Publications with scientific and technical data are covered and include statistics on population, economics, agricultural production, yield, prices, etc. Printed index is located in Documents Division.

ASSOCIATIONS' PUBLICATIONS IN PRINT, 1981-present, semiannual updates.
BRS

Available through this database is information on pamphlets, journals, newsletters, bulletins, books, and other fugitive print materials that are published by over 15,000 national, state, regional, local, and trade associations throughout the U.S. and Canada.

BIOGRAPHY MASTER INDEX, 3,000 B.C.-present, periodic updates.
DIS (287,288)

BMI is a master key to biographical information on nearly 2,000,000 persons who have distinguished themselves in hundreds of fields. It indexes approximately 700 separate editions and volumes of some 375 biographical source books, and corresponds to Gale Research Company's Biography and Genealogy Master Index and the microfiche Bio-Base. Each BMI record provides a person's name, birth and death dates, and titles of source books that provide complete biographical information on the person.

BOOK REVIEW INDEX, 1969-present, three updates per year.
DIS (137)

References to more than one million reviews of approximately 500,000 distinct book and periodical titles are accessible via this file produced by the Gale Research Company. BRI covers every review published in 300-400 periodicals and newspapers, from general interest and children's magazines to scholarly journals and newspapers. Records include the author and title of the publication reviewed and the name and bibliographic data of the journal in which it is reviewed. The database corresponds to the printed publication of the same name.

BOOKS IN PRINT, 1979-present, monthly updates.
BRS, DIS(470)

The online equivalent of the well-known Bowker indexes, this database offers timely access to the book trade, providing information on books in print or about-to-be-published titles as far as six months in advance. Included are books published by U.S. publishers or exclusively distributed in the U.S. and available to the trade or general public.

BOOKS INFORMATION, all books in print, monthly updates.
BRS

This database provides bibliographic, subject and price details for current books in print.

BOWKER'S BOOK ACQUISITION SYSTEM, current file, monthly updates.
BRS

This database permits direct ordering of any book from any U.S. publisher, distributor, or wholesaler. BAS retrieves full bibliographic information from Books in Print, and uses Bowker's Publishers, Distributors, and Wholesalers of the United States to obtain ordering information for more than 15,000 publishers in the nation.

CALIFORNIA UNION LIST OF PERIODICALS (CULP), current, monthly updates.
BRS

Produced by the California Library Authority for Systems and Services, CULP is a finding list for periodicals and serials held by over 600 special, public, community college, private, academic, state and federal agency libraries in California. Specifically intended for verification and interlibrary loan, the database includes cataloging information such as main entry, cross references, and preceeding and succeeding entries, as well as library locations and specific holdings.

CAREER PLACEMENT REGISTRY, current academic year, weekly updates.
DIS (163)

The CPR database contains the resumes of over 10,000 college and university seniors and recent graduates. The data are supplied by each job candidate on the basis of a questionnaire which provides name, address, phone numbers, citizenship status, schools, degrees, grades, occupation preferences, experience, function preferences, geographic preferences, date available, language skills, and other skills and achievements.

CAREER PLACEMENT REGISTRY/EXPERIENCED PERSONNEL, current six months, weekly updates.
DIS (162)

This database contains short resumes of men and women who have already been out in the work force and are now looking for a new job. Data in this file provide recruiters and potential employers access to job candidates on the basis of their personal background, career objectives, work experience, education, special skills, and unique qualifications. Data are supplied by each job candidate on the basis of a questionnaire which provides the above information as well as citizenship status, occupational and geographic preferences, salary requirements, language skills, and other qualifications.

CASSI, current edition, quarterly updates.
SDC

The online version of the printed Chemical Abstracts Service Source Index, this database provides full bibliographic information on more than 50,000 serial and non-serial publications. Availability information is derived from the holdings of over 400 participating libraries in 28 countries. This file is useful for bibliographic verification, location for interlibrary loans, acquisitions from publishers, tracing serial name changes, or identifying titles in a monographic series.

CIS INDEX, 1970-present, monthly updates.
DIS (101), SDC

This database is the machine-readable form of the Congressional Information Service's Index to Publications of the United States Congress and covers publications of the committees and subcommittees of the U.S Congress: Hearings, Committee prints, reports and other documents.

COFFEELINE, 1973-present, bimonthly updates.
DIS (164)

This database, produced by the International Coffee Organization (ICO), provides comprehensive bibliographic access to research and factual information about and relevant to coffee, including the economics of supply and demand, international trade, prices, agronomic and cultural aspects, processing technology, and physiological effects.

CONFERENCE PAPERS INDEX, 1973-present, monthly updates.
BRS, DIS (77)

Over 1,000 major scientific and technical meetings held worldwide and over 100,000 papers presented at or derived from these meetings are accessible through this database, which covers mainly the life sciences, chemistry, physical sciences, geosciences, and engineering.

CONGRESSIONAL RECORD ABSTRACTS, 1976-present (SDC), 1981-present (DIS), weekly updates.
DIS (135), SDC

Corresponding to the printed publication Congressional Record Abstracts, this databse provides concise summaries and references to bills and resolutions; committee and subcommittee reports; public laws; schedules of committee and floor actions; executive communications; and speeches, participation in debates, and materials inserted by members of the U.S. Congress.

DISSERTATION ABSTRACTS, 1861-present, monthly updates.
BRS, DIS (35)

Comprehensive Dissertation Abstracts provides coverage of doctoral dissertations from accredited American universities, most Canadian and an increasing number of foreign institutions. Professional and honorary degrees are not included but all subject areas are covered. Corresponds to the printed Comprehensive Dissertation Index, Dissertation Abstracts International (monthly updates), and American Doctoral Dissertations (annual updates).

ELECTRONIC YELLOW PAGES - PROFESSIONALS DIRECTORY, current data, semiannual updates.
DIS (502)

This file provides online yellow-page information for professionals in insurance, real estate, medicine, law, engineering, and accounting. Also included are hospitals and various medical laboratories and clinics. The database contains a full directory listing for each corporation, company, firm, or individual within those fields, and includes SIC codes and, where available, an indication of office size and city population.

FEDERAL RESEARCH IN PROGRESS, current research, semiannual updates.
DIS (265)

The FEDRIP database provides access to information about ongoing federally funded research projects in the fields of physical sciences, engineering, and life sciences. Produced by NTIS, FEDRIP continues, in part, the database functions of the now defunct Smithsonian Scientific Information Exchange (SSIE).

FOUNDATION DIRECTORY, current file, semiannual revisions.
DIS (26)

This file provides descriptions of non-profit, non-governmental foundations which make grants of $100,000 or more annually or which have assets of $1 million or more. Grants are given primarily in education, health, welfare, sciences, international activities and religion, in that order. Corresponds to the printed Foundation Directory published by the Foundation Center.

FOUNDATION GRANTS, 1972-present, bimonthly updates.
DIS (27)

Also published by the Foundation Center, this file contains information on grants awarded by major American philanthropic foundations. Grants of less than $5,000 and grants to individuals are not included; grants in the field of education are more prevalent.

GPO MONTHLY CATALOG, 1973-present, monthly updates.
BRS, DIS (66)

This file corresponds to the printed Monthly Catalog of United States Government Publications and is an index of public documents generated by the U.S. Federal Government printed by the Government Printing Office. It covers Congressional documents, Senate and House hearings on private and public bills and laws, as well as documents from other government agencies and departments on every major issue.

GPO PUBLICATIONS REFERENCE FILE, 1971-present, biweekly updates.
DIS (166)

The Government Printing Office PRF indexes the public documents currently for sale by the Superintendent of Documents, as well as forthcoming and recently out-of-print publications. These publications are generated by the legislative and executive branches of the U.S. Federal Government. The GPO PRF database corresponds to the microfiche GPO Sales Publications Reference File.

GRANTS, 1977-present, monthly updates and revisions.
DIS (85), SDC

In addition to grants awarded by private foundations, this file includes information on grants offered by federal, state and local governments, commercial organizations, and associations in over 88 academic disciplines. Its print counterparts are Grant Information System (GIS) and Faculty Alert Bulletin.

LC/LINE, 1968-present (MARC), 1969-present (MET), weekly updates.
SDC

This file covers the monographic literature, serials, maps, manuscripts, and other materials cataloged by the U.S. Library of Congress. It includes MARC records distributed by LC and MET (main entry/title) records created by 3-M Corporation, and covers English, French, German, Portuguese and Spanish literature. MET records cover English-language records from 1968-date plus Roman-alphabet and transliterated items since January 1978.

LC MARC, 1968-present, monthly updates.
DIS (426)

This is the file of book records distributed by the Cataloging Distribution Service of the U.S. Library of Congress. It is an international listing of books published in many countries and in many languages. LC MARC begins where REMARC leaves off.

MARQUIS WHO'S WHO, 1982-present, quarterly updates.
DIS(234)

Corresponding to the printed Who's Who in America and other titles in the Who's Who series (more included in future updates), this database contains detailed biographical information on outstanding professionals in all fields.

MATHFILE, 1973-present, monthly updates.
BRS, DIS(239)

The American Mathematical Society's database is the online version of Mathematical Reviews. It provides access to complete coverage of the research literature in pure and applied mathematics, physics, engineering, computer science, biology, operations research, and other disciplines that contain mathematics.

MILITARY AND FEDERAL SPECIFICATIONS AND STANDARDS, bimonthly updates.
BRS

Citations to all active and historical documents for Federal Specifications, Federal Standards, Joint Army-Navy Specifications, Military Specifications, and Military Standards can be retrieved through this database. Print counterparts are Military Specifications and Standards (numerical index), Military Standard Drawings, and Hot Specs.

NTIS, 1964-present (DIS), 1970-present (BRS, SDC), biweekly updates.
BRS, DIS (6), SDC

Though primarily a science and engineering database, this file, prepared by the National Technical Information Service, also contains some citations to U.S. government-sponsored research technical reports in the behavioral and social sciences, business and economics, health planning, and library and information sciences. Its printed counterparts are Weekly Government Abstracts and Government Reports Announcements.

NATIONAL FOUNDATIONS, 1975-present, annual updates and revisions.
DIS (78)

Records of all 20,000 U.S. foundations which award grants are provided in this file. Approximately 17,000 small foundations which are excluded from coverage in the FOUNDATION DIRECTORY because their assets total less than $1 million are listed in NATIONAL FOUNDATIONS, including those foundations which restrict their donations to local or regional recipients. This file overlaps and supplements the FOUNDATION DIRECTORY file where more complete data on the larger foundations are available.

NATIONAL NEWSPAPER INDEX, 1979-present, monthly updates.
DIS (111)

This file provides front page to back page indexing of The Washington Post, the Los Angeles Times, The Christian Science Monitor, The New York Times, and The Wall Street Journal. The only items not included are weather charts, stock market tables, crossword puzzles, and horoscopes. Provides a valuable adjunct in such areas as market research, public relations, government relations, journalism, food and nutrition and the social sciences.

NEWSEARCH, current month only, daily updates.
DIS (211)

The database is the daily update file for MAGAZINE INDEX AND NATIONAL NEWSPAPER INDEX. Information is transferred to those files at the end of every month.

NEWSPAPER INDEX, 1976-present, monthly updates.
SDC

The Chicago Tribune, Detroit News, Houston Post, Los Angeles Times, New Orleans Times-Picayune, San Francisco Chronicle and Washington Post are indexed for general news of international, national, state and local nature. Coverage is the same as the printed newspaper indexes.

NUC/CODES, current, monthly updates.
SDC

National Union Catalog Codes is a companion to the CASSI file for identification of holding library codes and library locations. This database consists of approximately 400 records giving the complete name and address of each holding library with its NUC code as it appears in the CASSI Availability field.

ONLINE CHRONICLE, October 1981-present, weekly updates.
DIS (170)

This database, an expanded version of the "NEWS" sections of both Online and Database magazines, is an electronic newsletter covering major online industry events, new databases, computer equipment, search aids, and people in the online world.

REMARC, 1897-1980, monthly updates
DIS(421-425)

The online version of the Library of Congress shelflist, this database contains bibliographic records representing the works cataloged by LC which are not included in the LC-generated MARC database.

SCISEARCH, 1974-present, biweekly updates.
DIS (34,87,94,186)

This file, a multidisciplinary index to the literature of science, technology and medicine, contains all the records published in the Science Citation Index. Over 2,600 major journals are indexed, which results in the inclusion of 90 percent of the world's significant scientific and technical literature.

SSIE, 1974-date, monthly updates.
DIS (65), 1978-1982, closed file.

This database contains reports of both government and privately funded scientific research projects either currently in progress or initiated and completed during the most recent two years. Approximately 90% of the work in progress is by agencies of the federal government, in such areas as behavioral and social sciences and economics. Continued in part by FEDERAL RESEARCH IN PROGRESS.

STANDARDS & SPECIFICATIONS, 1950 or earlier to present, monthly updates.
DIS (113)

This file provides titles and descriptive information for government and industry standards, specifications, and related documents which specify terminology, performance testing, safety, materials, products or other requirements and characteristics of interest to a particular technology.

SUPERINDEX, current editions, regular updates.
BRS

Encompassing all scientific and technical disciplines, this database contains several million searchable back-of-the-book index entries and page references to nearly 2,000 professional-level reference books published by over 20 prominent scientific, medical, and engineering publishers.

TERM, current vocabulary, quarterly updates.
BRS

This database consists of controlled vocabulary, category codes, subject codes, free-text synonyms and near synonyms for concepts in the social and behavioral sciences. The controlled vocabulary and codes are derived from the search aids and thesauri for five databases: ERIC, Family Resources, Medline, NIMH, and PsycINFO.

ULRICH'S INTERNATIONAL PERIODICALS DIRECTORY, current edition.
BRS, DIS (480)

This online version of the Ulrich's printed index provides information on 65,000 periodicals and 38,500 serials, annuals, continuations, conference proceedings, and other publications from all over the world. It is particularly useful for verifications and acquisitions.

UPI NEWS, 1983-present, daily (File 261) and monthly (File 260) updates.
DIS (260, 261)

The full text of news stories carried on the United Press International wire is included in this database. The records appear online 48 hours after the data are transmitted. Included is all news currently transmitted by UPI in the following categories: domestic general news, columns and standing features, financial news, international news, commentaries, and Washington, D.C., news.

U.S. GOVERNMENT CONTRACT AWARDS, FY 78-date, monthly updates.
SDC

Like the printed U.S. Contract Awards and sections of the Commerce Business Daily, this file contains all contract awards by the U.S. Government in fields of conservation, energy, education and human development, urban systems, etc.

USPA/USP77/USP70, 1970-present, weekly updates.
SDC

These three files provide bibliographic information and the full text of all the claims which completely define the scope of protection for inventions patented in the U.S. since 1970.

VENDOR INFORMATION DATABASE, current catalog information, monthly updates.
BRS

This file contains information from catalogs of over 30,000 vendors of industrial products. Included are architectural engineering, distributors, plant engineering, transportation and materials handling, medical equipment and supplies, construction and building products, electrical and electronic engineering, and marine and metric design. Extensive descriptive information is provided.

VOLUNTARY STANDARDS INFORMATION NETWORK, current file, semimonthly updates.
BRS

VSIN contains information about standards under development by the voluntary standards organizations which are listed for public review by ANSI, as well as those voluntary standards that are under development by the signatories to the GATT Agreement on Technical Barriers to Trade (Standards code). The print counterpart is ANSI Standards Action.

WASHINGTON POST INDEX, 1979-present, monthly updates.
DIS(184)

Corresponding to the microfilm edition of the Washington Post, this database is an index to all significant material appearing in the daily Post as well as all three regional weeklies (Va., Md., and DC).

WILEY CATALOG/ONLINE, 1940-present, bimonthly updates.
DIS (471)

The online version of John Wiley & Sons General Catalog, this databas contains records for virtually all products published, sold, or distributed by wiley, including books, software, databases, journals, and other publications currently available and forthcoming.

BIOLOGICAL AND LIFE SCIENCES

AGRICOLA, 1970-present, monthly updates.
BRS, DIS (10, 110),

Produced by the National Agricultural Library of the U.S. Department of Agriculture, this database provides comprehensive worldwide coverage in the field of agriculture and such related fields as rural sociology, agricultural economics, veterinary medicine, plant science, agricultural chemistry, soils, water management, food and nutrition. Corresponds to the printed Bibliography of Agriculture.

AQUACULTURE, 1970-present, irregular updates.
DIS (112)

Produced by the National Oceanic and Atmospheric Administration (NOAA), this file provides information on the growing of marine, brackish, and freshwater organisms, covering such subjects as growth requirements, economics, and nutrition of water organisms. Hydroponics are excluded. There is no printed equivalent.

AQUATIC SCIENCES AND FISHERIES ABSTRACTS, 1978-present, monthly updates.
DIS (44)

The publications Aquatic Sciences and Fisheries Abstracts; Part 1: Biological Sciences and Living Resources and Part 2: Ocean Technology, Policy, and Non-Living Resources are the print versions of this file, which covers the science, technology and management of marine and freshwater environments.

BIOSIS PREVIEWS, 1969-present, monthly updates.
BRS, DIS (5,55,255)

This file, which corresponds to the printed Biological Abstracts and Bioresearch Index, covers all areas of the life sciences, including bioengineering, biophysics, genetics, behavioral sciences, pharmacology, public health, veterinary science and virology.

CAB ABSTRACTS, 1972-present, monthly updates.
DIS (50)

This comprehensive file of agricultural information contains all records in the abstracting journals published by the Commonwealth Agricultural Bureaux. Significant papers are abstracted and less important works are reported with bibliographic details only in every branch of agricultural sciences, including education, genetics, pest control and taxonomy.

*CHEMICAL ABSTRACTS, 1967-present, biweekly updates.
BRS, DIS (308,309,310,311,320), SDC

Corresponding to the printed Chemical Abstracts minus the abstracts, this file provides comprehensive coverage of the literature of chemistry and its applications. Patents, books, conference proceedings and government research reports are included; subject divisions include applied chemistry and chemical engineering, biochemistry, macromolecular chemistry, organic chemistry, physical and analytical chemistry.

CHEMICAL EXPOSURE, 1974-present, annual updates.
DIS (138)

This is a comprehensive database of chemicals that have been identified in both human tissues and body fluids and in feral and food animals. The data identify body burdens which reflect exposures to contaminants and pharmaceuticals. The database corresponds to the printed works, Chemicals Identified in Human Biological Media, A Data Base and Chemicals Identified in Feral and Food Animals, A Data Base.

CRIS/USDA, active and recently completed projects, monthly updates.
DIS (60)

Current Research Information System/USDA provides access to agricultural and related research information. The projects described cover current research sponsored or conducted by the U.S. Department of Agriculture research agencies, state agricultural experiment stations, state forestry schools, and other cooperating state institutions. A wide range of topics is covered, including biological, physical, social and behavioral sciences; family life and housing; environmental protection and resource management; outdoor recreation and community development; marketing and economics; food and nutrition; textiles and clothing; consumer health and safety; and others.

CURRENT BIOTECHNOLOGY ABSTRACTS, 1983-present, monthly updates.
PIL

CBA provides extensive coverage of the scientific, technical, and technocommercial literature of the multidisciplinary subject of biotechnology, including business and safety news, legal issues, genetic manipulation, monoclonal antibodies, enzymology, single cell proteins, fermentation technology, pharmaceuticals, energy production, agriculture, chemical industry, and food.

EXCERPTA MEDICA, June 1974-present, monthly updates.
DIS (72,73,172)

This file covers the biomedical literature throughout the world and includes all fields of medicine and health related sciences, such as anthropology, psychiatry, and public health. Same as printed Excerpta Medica abstract journals.

*FOOD SCIENCE AND TECHNOLOGY ABSTRACTS (FSTA), 1969-present, monthly updates.
DIS (51), SDC

This file, which corresponds to the printed Food Science and Technology Abstracts, covers literature related to all human food commodities and aspects of food processing except the production of raw foods. Allied disciplines such as agriculture, chemistry, biochemistry, physics, home economics and engineering are also covered.

LABORATORY HAZARDS BULLETIN, 1981-present, monthly updates.
PIL

This database contains information from the literature on hazards likely to be encountered by the chemical and biochemical laboratory research worker. Included are hazardous chemicals and reactions, new safety precautions, new legislation, and biological hazards.

LIFE SCIENCES COLLECTION, 1978-present, monthly updates.
DIS (76)

This file contains bibliographic citations and abstracts from recent worldwide literature in major areas of biology, medicine, biochemistry, ecology, and microbiology, and in some aspects of agriculture and veterinary science. Produced by Information Retrieval Ltd., this database corresponds to the printed series of 15 IRL abstracting journals.

MEDLINE (MEDLARS), 1966-present, monthly updates.
BRS, DIS (152, 153,154)

Corresponds to the print Index Medicus, Index to Dental Literature and the International Nursing Index and covers all types of medical sciences literature.

MEDOC, 1976-present, quarterly updates.
BRS

This file provides access to government documents in the health sciences.

NAL SERIALS, 1978-present, monthly updates.
BRS

This file provides a listing of all serial records of the National Agricultural Library.

TELEGEN, 1973-present, monthly updates.
DIS(238)

This file provides access to information related to biotechnology and genetic engineering. It corresponds to the print publication Telegen Reporter.

TROPAG, 1975-present, monthly updates.
SDC

Corresponding to the printed Abstracts on Tropical Agriculture, this file contains citations to the literature on tropical and subtropical agriculture. Topics covered include crop production, protection, processing, and storage; soils and fertilizers; plant nutrition; agricultural techniques; and sociological, economic, commercial, and statistical information. Also covered are such areas as animal husbandry, inland fisheries, forestry, human nutrition, and public health. Special attention is paid to applied, local information of use to agricultural development workers.

WATERLIT, 1976-present, monthly updates.
SDC

This database provides coverage of international literature relating to water and water resources. Topics include atmospheric water, hydrology, ground water, dams, pipelines, canals, pumps, valves, reservoirs, water treatment, wastewater, solid waste, pollution, and other water-related subjects.

ZOOLOGICAL RECORD, 1978-present, bimonthly updates.
DIS (185)

Provides extensive coverage of the world's zoological literature with particular emphasis on systematic/taxonomic information.

CHEMICAL SCIENCES

AMERICAN CHEMICAL SOCIETY PRIMARY JOURNAL DATABASE, 1980 (1976)-present, biweekly updates.
BRS

Available in this database is full text coverage of articles appearing in 18 primary chemistry journals published by the American Chemical Society.

CEH INDEX
SDC

This online index to CHEMICAL ECONOMICS HANDBOOK is used to identify index entries and cross references to table data contained in that database.

CHEMDEX, 1972-present, quarterly updates.
SDC

This dictionary file covers all compounds cited in the literature. It can be searched by chemical name, molecular formula, or by group or row within the periodic chart. The print publications are CA Substance Index, CA Registry Handbook, CA Index Guide, and CA Formula Index.

*CHEMICAL ABSTRACTS, 1967-present, biweekly updates.
BRS, DIS (308, 309, 320, 310, 311), PIL, SDC

This file corresponds to the printed Chemical Abstracts and provides comprehensive coverage of the literature of chemistry. Patents, books, conference proceedings and government research reports are included. Subject divisions are: applied chemistry and chemical engineering, biochemistry, macromolecular chemistry, organic chemistry, physical and analytical chemistry. From 1972 onward, the CASIA files are integrated into the DIS and SDC files, providing additional index entries and CAS Registry Numbers.

CHEMICAL ECONOMICS HANDBOOK, current edition, monthly updates.
SDC

This file provides, in tabular form, comprehensive data and studies of the history and status of more than 1300 major commodity and specialty chemicals, petrochemicals, intermediates, polymers, agricultural chemicals, as well as data on chemical-related industries and general U.S. economic indicators.

CHEMICAL ENGINEERING ABSTRACTS, 1970-present, monthly updates.
PIL

Available here are abstracts of scientific and technical literature on all aspects of chemical engineering. Mechanical, civil, electrical, and instrumentational areas of chemical engineering are included. The database corresponds to the printed publication of the same title and includes material selected from over 100 of the world's major primary chemical and process engineering journals.

CHEMICAL EXPOSURE, 1974-present, annual updates.
DIS (138)

This is a comprehensive database of chemicals that have been identified in both human tissues and body fluids and in feral and food animals. The data identify body burdens which reflect exposures to contaminants and pharmaceuticals. The database corresponds to the printed works, Chemicals Identified in Human Biological Media, A Data Base and Chemicals Identified in Feral and Food Animals, A Data Base.

CHEMICAL INDUSTRY NOTES (CIN), 1974-present, weekly (SDC) and monthly (DIS) updates.
DIS (19), SDC

Corresponding to the printed Chemical Industry Notes, this database contains articles which cover the following chemical industry areas: production, pricing sales facilities, products and processes, corporate activities, government activities, and people in the chemical industry.

CHEMICAL REGULATIONS AND GUIDELINES SYSTEM (CRGS), current file, monthly updates.
DIS (174)

CRGS is an authoritative index to U.S. federal regulatory material relating to the control of chemical substances, covering federal statutes, promulgated regulations, and available federal guidelines, standards, and support documents. Each chemical cited in a regulatory document is indexed by name, CAS Registry Number, and a chemical role tag. All aspects of regulatory control of chemicals are covered, in fields such as aeronautics, agriculture, consumer products, cosmetics, energy, environmental protection, food, mining, nuclear technology, petrochemicals, pharmaceuticals, and transportation.

CHEMLAW, current and final regulations, irregular updates.
DIS (197)

This database contains the full text of U.S. federal chemical regulations as published in the Code of Federal Regulations and as updated by the Federal Register. Included are regulations relating to the manufacture, processing, use, storage, transportation, disposal, or occupational effects of chemical substances.

CHEMNAME, 1967-present, quarterly updates.
DIS (301)

This file contains a listing of chemical substances in a dictionary-type non-bibliographic file. For each substance listed, the CAS Registry Number, molecular formula, CA Substance Index Names, available synonyms, ring data and other chemical substance data are listed for those substances which have been referenced two or more times from 1967 through the most recent update.

CHEMSEARCH, latest six weeks, updated biweekly.
DIS (30)

This file is a dictionary listing of the most recently cited chemical substances in the CHEMICAL ABSTRACTS file, to provide access to chemical substance nomenclature using CAS Registry Numbers for new compounds.

CHEMSIS, 1972-present, irregular updates.
DIS (328,329, 330)

This is the chemical substance dictionary for singly indexed substances cited since 1972. Information provided for each substance listed includes CAS Registry Number, molecular formula, CA Substance Index Names, available synonyms, and ring data. This is a companion file to CHEMNAME (file 301), which contains substances cited more than once since 1967.

CHEMZERO, 1965-present, irregular updates.
DIS (300)

This is the chemical substance dictionary for which there are no citations in the online CHEMICAL ABSTRACTS databases since 1967. Information provided for each substance includes CAS Registry Number, molecular formula, CA Substance Index Names, and available synonyms. This file provides access to all substances registered by CAS whether cited or not in the literature.

CLAIMS COMPOUND REGISTRY, 1950-present, annual updates.
DIS (242)

This is a dictionary-type, non-bibliographic file containing records for specific chemical compounds. It is designed for locating compounds of interest for further searching in the CLAIMS UNITERM patent files (DIS-223, 224, 225). Each record contains the IFI compound number and name, synonyms, molecular formula, element count, fragment codes, and corresponding fragment terms.

COMPENDEX, 1970-present, monthly updates.
DIS (8), SDC

This machine-readable version of the Engineering Index provides information from the world's significant literature in engineering and related subject areas, including chemical engineering, materials' properties and testing. It covers about 3,500 journals, publications of engineering societies and organizations, papers from the proceedings of conferences and selected government reports and books.

FINE CHEMICALS DIRECTORY, current file, irregular updates.
PIL

This database is a comprehensive automated catalog of commercially available research chemicals. It covers sources for organics, biochemicals, dyes, stains, and some inorganics. Included are catalog entries from over 30 international chemical suppliers.

HAZARDLINE, current file, monthly updates.
BRS

Available in this database is regulatory, handling, identification, and emergency care information for over 3,000 substances. Included are descriptions of substances; permissible exposure levels; incompatibilities; requirements for protective clothing, respirator use, and medical surveillance; symptoms and first aid treatment; regulatory status (including court decisions); and procedures for handling spills and waste.

KIRK-OTHMER, current edition
BRS

This online version of the Kirk-Othmer Encyclopedia of Chemical Technology offers full-text access to textual information and numeric data in wide range of chemistry-related subject disciplines. Included are the numerous tables which summarize chemical and physical properties, production figures and capacity, processes, uses and applications, and health and safety guidelines. Lengthy tables are segmented so that relevant table portions can be displayed.

LABORATORY HAZARDS BULLETIN, 1981-present, monthly updates.
PIL

This database contains information from the literature on hazards likely to be encountered by the chemical and biochemical laboratory research worker. Included are hazardous chemicals and reactions, new safety precautions, new legislation, and biological hazards.

MASS SPECTROMETRY BULLETIN, 1966-present, monthly updates.
PIL

Available through this file are bibliographic citations to documents in the field of mass spectrometry and allied subjects such as instrument design and techniques, isotopic analysis, chemical analysis, organic chemistry, atomic and molecular processes, surface phenomena and solid state studies, thermodynamics and reaction kinetics.

*PAPERCHEM, 1968-present, monthly updates.
DIS (240),SDC

This database, which corresponds to the printed publication Abstract Bulletin of the Institute of Paper Chemistry, provides comprehensive worldwide coverage of the scientific and technical literature that deals with the theoretical principles, technologies, raw materials, products, and practices of the pulp-, paper-, and board-manufacturing and -utilizing industries.

TSCA INITIAL INVENTORY, 1975-present, irregular updates.
DIS (52), SDC

This file lists approximately 57,000 chemical substances in commerce in the United States. CAS Registry Number, preferred name, synonyms and molecular formula are included for each substance. The hardcopy version is called Initial Inventory of the Toxic Substances Control Act (TSCA) Chemical Substance Inventory.

ZINC, LEAD, AND CADMIUM ABSTRACTS, 1975-present, monthly updates.
PIL

ZLC covers all aspects of the production, properties, and uses of these metals, their alloys and compounds. The database corresponds to the printed publications Lead Abstracts, Zinc Abstracts, and Cadmium Abstracts, plus additional records that do not appear in the abstract publications.

COMPUTERS AND DATA PROCESSING

COMPUTER DATABASE, 1983-present, semimonthly updates.
DIS (275)

Provides wide-ranging information on computers, telecommunications, and electronics. Coverage ranges from detailed consumer information on products, companies, and people to highly technical information on programming and circuit design. Offers cover-to-cover indexing and abstracting of over 500 computer-related publications in addition to significant coverage in the telecommunications and electronics fields from periodicals, books, courses, tabloids, newsletters, and research reports.

*COMPUTERPAT, 1942-present, weekly updates.
PIL

This database contains abstracts and bibliographic data for all U.S. digital data processing patent documents as classified by the U.S. Patent and Trademark Office in subclasses 364/200 and 364/900.

DISC, 1982-present, biweekly updates.
BRS

Data Processing and Information Science Contents provides access to microcomputing literature in leading journals, as well as to peripheral and related data on mini systems, information science, and EDP.

ELECTRONIC PUBLISHING ABSTRACTS, 1975-present, semimonthly updates.
PIL

This file gives summaries of the literature in electronic publishing and information technology. In particular it covers the machine readable input, transmission, storage, and retrieval of text and images as an alternative to the publication of printed documents.

*INSPEC, 1969-present, monthly updates.
BRS, DIS (12,13), SDC

The online INSPEC file corresponds to the printed Physics Abstracts, Electrical and Electronics Abstracts, Computer and Control Abstracts, and IT Focus and provides coverage of the applied energy literature in physics, electrical and electronics engineering, journal articles, government reports, patents, technical reports, books, conference proceedings, and theses are included.

INTERNATIONAL SOFTWARE DATABASE, 1973-present, monthly updates.
DIS(232)

ISD provides a comprehensive collection of information about more than 10,000 computer programs (software) specifically designed for use with microcomputers and minicomputers. Software vendors throughout the world contribute information to ISD about their available programs and packages. International Microcomputer Software Directory and International Minicomputer Software Directory are the printed works corresponding to this database.

MICROCOMPUTER INDEX, 1981-present, monthly updates.
DIS(233)

This is a subject and abstract guide to microcomputer articles from more than 25 English-language microcomputer periodicals. Broad coverage of the subject of microcomputers is provided by this database, which corresponds to the printed publication of the same name.

ONLINE MICROCOMPUTER SOFTWARE GUIDE AND DIRECTORY, current edition, monthly updates.
BRS

This database supplies current microcomputer software product descriptions plus related information on costs, applications, purchase, hardware requirements, documentation availability, operating environment specifications, and other software used with the package. Producer comments and critical review information are also included. Corresponds to the print Online Micro-Software Guide and Directory

ENERGY

*CHEMICAL ABSTRACTS, 1967-present, biweekly updates.
BRS, DIS (308,309,310,311,320), PIL, SDC

This file corresponds to the printed Chemical Abstracts and provides comprehensive coverage of the literature of chemistry, including energy chemistry literature and patents.

COMPENDEX, 1970-present, monthly updates.
BRS, DIS (8), PIL, SDC

This machine-readable version of the Engineering Index provides information from the world's significant literature in engineering and related subject areas, including transportation, mining engineering, petroleum engineering, nuclear technology, heat and thermodynamics.

DEPARTMENT OF ENERGY DATABASE, 1974-present, monthly updates.
BRS, DIS(103), SDC

Produced by the DOE Technical Information Center, this database offers wide coverage of all topics of interest to the Department of Energy, including solar, tidal, wind, geothermal, and nuclear fusion energy; fossil and synthetic fuels; energy conservation, consumption, management, storage, and conversion; advanced automotive systems, electric power engineering; environmental and biomedical sciences with reference to energy technology; particle accelerators; explosions; isotope and radiation source technology; and research, engineering, and instrumentation directly relevant to DOE programs. All unclassified information processed at the Technical Information Center is included in the database.

EBIB, 1966-present, periodic updates.
SDC

An excellent source for retrospective energy information, this database corresponds to the Energy Bibliography and Index of all energy-related materials in the Texas A & M Library. Some material dates back to the 19th century, but the majority of materials are of recent publication (1970's and 1980's). A special feature of the file is its coverage of German World War II documents on synthetic fuel technology. Subjects covered include production, utilization, and conservation of fuels; energy storage and conversion; energy policy; alternative energy sources, power plants and transmission systems; and economic, political, environmental, and statistical aspects of energy-related issues and activities.

ELECTRIC POWER DATABASE, 1972-present, monthly updates.
DIS (241)

Produced by the Electric Power Research Institute (EPRI), this database consists of project summaries of research and development projects of interest to the electric power industry. Included are approximately 8,500 research projects conducted by EPRI member utilities, EPRI contractors, and other utilities. Major subject areas include hydroelectric power, fossil fuels, nuclear power, customer utilization, general R & D support, transmission, distribution, economics, personnel, advanced power systems, stations and substations, area development, and environmental assessment. This file is the online equivalent of the Digest of Research in the Electric Utility Industry.

ELECTRIC POWER INDUSTRY ABSTRACTS, 1975-present, five updates per year.
SDC

Formerly called INFORUM, EPIA is produced by the Atomic Industrial Forum's technical information service. It provides access to the literature on environmental aspects of new power plants and related facilities. Literature covered includes technical reports and studies by electrical utilities and consultants; reports prepared by Federal and state agencies, siting commissions, and control boards; and selected journal articles, conference proceedings, and congressional hearings.

ENERGYLINE, 1971-present, bimonthly updates.
BRS, DIS (69), SDC

Energy Information Abstracts is the print version of this file, which also includes energy-related records from Environmental Abstracts. It provides information on scientific, technical, socioeconomic, governmental policy and planning and current affairs aspects of energy.

ENERGYNET, current quarter's data, quarterly updates.
DIS (169)

The ENERGYNET database contains up-to-date, directory-type information on over 3,000 organizations and 8,000 people in energy-related fields, including profit and non-profit organizations and government agencies. Each record contains organization information; names, addresses, and phone numbers of key energy contacts, and a narrative description of the organization's goals and activities.

FEDERAL ENERGY DATA INDEX (FEDEX), 1977-present, quarterly updates.
BRS

This file contains bibliographic references to all publications produced by the Energy Information Administration of the U.S. Department of Energy. The EIA is responsible for collecting and publishing statistical data on actual and projected energy resource reserves, energy production and consumption, supply and demand, prices, and related economic information.

*INSPEC, 1969-present, monthly updates.
BRS, DIS (12,13), SDC

The online INSPEC file corresponds to the printed Physics Abstracts, Electrical and Electronics Abstracts, and Computer and Control Abstracts and provides coverage of the applied energy literature in physics, electrical and electronics engineering. Journal articles, government reports, patents, technical reports, books, conference proceedings, and theses are included.

ISMEC, 1973-present, monthly updates.
DIS (14)

ISMEC (Information Service in Mechanical Engineering) covers leading international journals and conferences on mechanical engineering subjects, including mechanical, nuclear, electrical, electronic, civil, optical, medical and industrial process engineering; mechanics; production processes, energy and power. Its print version is the ISMEC Bulletin.

P/E NEWS, 1975-present, weekly updates.
SDC

This database, which has no printed correspondent, covers energy and petroleum business news from six major sources: Middle East Economic Survey, The Oil Daily, The Petroleum Economist, Petroleum Intelligence Weekly, Platt's Oilgram News Service, and National Petroleum News.

POWER, 1950-present, bimonthly updates.
SDC

This database represents the complete cataloging records for the main book collection of the Department of Energy's Energy Library. The library brings together several significant government agency collections, including those of the former Atomic Energy Commission, the Energy Research and Development Administration, the Federal Power Commission, and the Federal Energy Administration. Also included are all non-serial publications currently of interest to DOE. This database is especially strong in coverage of general works on energy, physical and environmental sciences, technology, and economics of renewable resources.

*TULSA, 1965-present, weekly updates.
SDC

This database corresponds to the printed Petroleum Abstracts and provides coverage of literature and patents related to exploration, development and production of petroleum and other fossil fuels, including natural gas and coal.

ENGINEERING

*BHRA FLUID ENGINEERING, 1974-present, monthly updates.
DIS (96)

This file provides indexing and abstracting of world-wide information on all aspects of fluid engineering, including theoretical research as well as technology and applications. Fields covered include civil engineering, hydraulics, fluid flow, fluidics feedback and tribology. No print counterpart.

CHEMICAL ENGINEERING ABSTRACTS, 1970-present, monthly updates.
PIL

Available here are abstracts of scientific and technical literature on all aspects of chemical engineering. Mechanical, civil, electrical, and instrumentational areas of chemical engineering are included. The database corresponds to the printed publication of the same title and includes material selected from over 100 of the world's major primary chemical and process engineering journals.

COLD REGIONS, 1962-date, quarterly updates.
SDC

This database, which corresponds to the printed Antarctic Bibliography and the Bibliography on Cold Regions Science and Technology, provides coverage of areas affected by freezing temperatures, as they related to such fields as civil engineering, navigation, transportation and operation of equipment in cold weather.

COMPENDEX, 1970-present, monthly updates.
BRS, DIS (8), PIL, SDC

Engineering Index is the printed version of this file, which covers the world's significant engineering and technological literature. It includes coverage of approximately 3,500 journals, publications of engineering societies and organizations, papers, conference proceedings, government reports and books.

CORROSION, current file, semiannual updates.
SDC

This database can assist the engineer in selecting construction material. It covers the effects of over 600 agents on metals, carbon, glass, plastics, and rubbers, over a temperature range of 60 - 560 degrees Fahrenheit for metals and 40 - 460 degrees Fahrenheit for plastics and rubbers. Corresponds to the printed publication, Corrosion Resistance Tables: Metals, Plastics, Nonmetallics, and Rubbers.

EI ENGINEERING MEETINGS, 1982-present, monthly updates.
DIS (165), SDC

This companion file to COMPENDEX indexes significant published proceedings of engineering and technical conferences, symposia, meetings, and colloquia from over 40 different countries.

IBSEDEX, 1979-present, monthly updates
PIL

This database covers all aspects of the mechanical and electrical services in buildings, from controls and instrumentation to energy management and sources, to site and office organization, to services for handicapped and disabled persons.

INDUSTRY AND INTERNATIONAL STANDARDS, active standards, bimonthly updates.
BRS

This database includes citations to Voluntary Engineering Standards from all standardizing bodies in the U.S., selected foreign national standards, and major international standards. The data cover all aspects of engineering and related services. Print counterparts are VSMF Industry Standards and VSMF International and Foreign National Standards.

*INSPEC, 1969-present, monthly updates.
BRS, DIS (12,13), SDC

The online INSPEC file corresponds to the printed Physics Abstracts, Electrical and Electronics Abstracts, Computer and Control Abstracts, and IT Focus and provides coverage of the applied energy literature in physics, electrical and electronics engineering, journal articles, government reports, patents, technical reports, books, conference proceedings, and theses are included.

ISMEC, 1973-present, monthly updates.
DIS (14)

The ISMEC Bulletin is the print counterpart of this database, which covers leading international journals, books and conferences on all aspects of mechanical engineering, production engineering, and engineering management.

METADEX (METALS ABSTRACTS/ALLOYS INDEX), 1966-present, monthly updates.
DIS (32), SDC

This file provides comprehensive coverage of international literature on the science and practice of metallurgy. Six basic categories of metallurgy are covered: materials, processes, properties, products, forms and influencing factors. The print versions are: Review of Metal Literature (1966-67), Metals Abstracts (1968-present), and Alloys Index (1974-present).

METALS DATAFILE, monthly updates.
SDC

This numeric database provides access to Designation and Specification numbers for each metal or alloy, element concentrations, physical properties, uses, forms, and other information necessary for the design engineer.

*NONFERROUS METALS ABSTRACTS, 1961-present, monthly updates.
DIS (118)

This database, which corresponds to the printed BNF Non-Ferrous Metals Abstracts, provides coverage of the international literature relevant to metallurgy; metal finishing, corrosion, extraction, production, properties, fabrication, uses, and processing; metallography; company information; economics, analysis, and testing.

PIRA, 1975-present, monthly updates.
PIL

PIRA is a machine-readable version of Paper and Board Abstracts, Printing Abstracts, Packing Abstracts, and Management and Marketing Abstracts. It includes periodicals, books, standards, specifications, legislation, conference papers, research reports and other information in the fields of paper and board manufacturing.

RAPRA ABSTRACTS, 1972-present, monthly updates.
PIL

RAPRA (Rubber and Plastics Research Association) is a comprehensive database covering the commercial, technical and research aspects of the rubber and plastics industries. Subjects covered include: synthesis and polymerization, processing technology, properties and testing.

ROBOTICS INFORMATION, 1980 (1970) - present, monthly updates.
BRS

This database offers coverage of English language and selected foreign literature on the technical and business aspects of robotics.

SAE, 1965-present, quarterly updates.
SDC

This database, produced by the Society of Automotive Engineers, provides access to a select number of technical papers on the technology of the automotive and automotive-related industry.

TRIS, 1968-present, monthly updates.
DIS (63)

The database of the Transportation Research Board of the National Research Council provides information from a combination of four transportation research information services: The Highway Research Information Services (HRIS), the Maritime Research Information Service (MRIS), the Railroad Research Information Services (RRIS), and the Air Transportation Research Information Service (ATRIS), and covers such facets of transportation research as administration, regulations, safety concerns, construction, and performance.

WATERLIT, 1976-present, monthly updates.
SDC

This database provides coverage of international literature relating to water and water resources. Topics include atmospheric water, hydrology, ground water, dams, pipelines, canals, pumps, valves, reservoirs, water treatment, wastewater, solid waste management, agriculture, limnology, water law and economics, ecology, fisheries, chemicals, pollution, and other water-related subjects.

*WELDASEARCH, 1967-present, monthly updates.
DIS (99)

The WELDASEARCH database provides coverage of the international literature on all aspects of the joining of metals and plastics and related areas such as metals spraying and thermal cutting. Information is extracted from several thousand journals, research reports, books, standards, patents, theses and special publications.

*WORLD TEXTILES, 1970-present, monthly updates.
DIS (67)

This is the machine-readable version of World Textile Abstracts and indexes world literature on the science and technology of textile and related materials, including the synthesis, physics and chemistry of polymers for fibers. Its coverage is roughly the same as that of the TITUS file.

ZINC, LEAD, AND CADMIUM ABSTRACTS, 1975-present, monthly updates.
PIL

ZLC covers all aspects of the production, properties, and uses of these metals, their alloys and compounds. The database corresponds to the printed publications Lead Abstracts, Zinc Abstracts, and Cadmium Abstracts, plus additional records that do not appear in the abstract publications.

ENVIRONMENT

APTIC, 1966-September 1978, closed file.
DIS (45)

This Air Pollution Technical Information Center database covers all aspects of air pollution, its effects, prevention and control, including the social, political, legal and administrative aspects of the field. Includes all entries from Air Pollution Abstracts (no longer published).

AQUALINE, 1969-present, monthly updates.
DIS (116)

This database provides worldwide-coverage of all aspects of water research, including waste water and the aquatic environment. It contains all of the material from the printed abstracts journal WRC Information and additional supplementary material including conference papers and items of specialized interest. Areas of subject interest include water resource development and management; water quality and treatment; distribution and sewage systems; sludge disposal; groundwater pollution; water monitoring, sampling, and analysis; environmental protection.

*ENVIROLINE, 1971-present, monthly updates.
BRS, DIS (40), SDC

Environment Abstracts is the printed title corresponding to this file, which covers the world's environmental information. Over 5,000 source publications are covered in such fields as management, law, economics, geology, biology, and chemistry as they relate to the environment.

ENVIRONMENTAL BIBLIOGRAPHY, 1974-present, bimonthly updates.
DIS (68)

The Environmental Periodicals Bibliography is the printed version of this file, which indexes over 150 periodicals to provide information about general human ecology, atmospheric studies, energy, land resources, water resources, and nutrition and health.

FOREST, 1947-date, bimonthly updates.
SDC

This database of the Forest Products Research Society covers worldwide literature pertinent to the entire wood products industry, from harvesting through marketing. There is no corresponding printed publication.

IRIS, 1979-present, semiannual updates.
DIS (53)

INSTRUCTIONAL RESOURCES INFORMATION SYSTEM is a specialized file of educational and instructional materials on water quality and water resources. Additional subject areas covered include water treatment, pollution control, disposal, and quality monitoring; safety and standards; pesticides and toxic substances; and career and occupational information. The IRIS database is the online version of the printed Water Quality Instructional Resources Information System produced by the EPA Information Project at Ohio State University.

OCEANIC ABSTRACTS, 1964-present, bimonthly updates.
DIS (28)

This database, the online version of Oceanic Abstracts, covers worldwide technical literature on oceans, seas, and marine-related subjects, including geology, optics, mining, diving, ships, and laws and regulations.

PACIFIC ISLANDS ECOSYSTEMS (PIE), 1927-present, annual updates.
SDC

This is a multidisciplinary database providing information on the Pacific islands in Polynesia and Micronesia under U.S. jurisdiction. Primary topics are the biological, ecological, physical, and socioeconomic processes and features of the costal ecosystems of the Pacific islands, and of man's impact on the environment.

POLLUTION ABSTRACTS, 1970-present, bimonthly updates.
BRS, DIS (41)

Pollution Abstracts is the printed publication corresponding to this file, which contains references to environmentally related literature on pollution, its sources and its control.

SELECTED WATER RESOURCES ABSTRACTS, 1968-present, monthly updates.
DIS (117),

SWRA consists of abstracts and references to documents on all water-related aspects of the life, physical, and social sciences. Specific topics include quality and quantity management, supply augmentation and conservation, resources planning data, grants, and facilities, as well as material on engineering and legal aspects of the characteristics, conservation, control, use, and management of water. This database corresponds to the printed publication of the same name produced by the U.S. Department of the Interior's Office of Water Research and Technology.

WATERLIT, 1976-present, monthly updates.
SDC

This database provides coverage of international literature relating to water and water resources. Topics include atmospheric water, hydrology, ground water, dams, pipelines, canals, pumps, valves, reservoirs, water treatment, wastewater, solid waste management, agriculture, limnology, water law and economics, ecology, fisheries, chemicals, pollution, and other water-related subjects.

WATERNET, 1971-present, quarterly updates.
DIS(245)

Produced by the American Water Works Association, this is a comprehensive index of literature dealing with water quality, water utility management, testing procedures, water use and reuse, environmental issues, energy-related economics, water law, toxicological and medical related data, water rates and conservation, financing and administration, etc.

Barbara Ritzma

Ken

GEOSCIENCES

*CHEMICAL ABSTRACTS, 1976-present, biweekly updates.
BRS, DIS (308,309,310,311,320), PIL, SDC

This file corresponds to the printed Chemical Abstracts and provides access to the technical literature for chemistry and chemical engineering, geochemistry and related fields.

GEOARCHIVE, 1974-present, monthly updates. *
DIS (58)

Geophysics, geochemistry, geology, paleontology, and mathematical geology are covered in this database which indexes books, conferences, serials, dissertations, maps and technical reports. It has no printed equivalent, but among the publications printed from the information contained in the database are Geotitles Weekly, Geocom Bulletin, Geoscience Documentation, and the Bibliography of Vertebrate Paleontology.

GEOMECHANICS ABSTRACTS, 1977-present, bimonthly updates.
PIL

This database covers the published literature on rock mechanics, soil mechanics, and engineering geology. Corresponding to the printed publication of the same title, it covers such subjects as properties of rocks and soils, rock and soil masses, mining, tunnelling, support, slope stability, comminution, rock and soil improvement techniques, site investigation, and laboratory and field tests.

GEOREF, 1929-present, monthly updates. $92/hr + 30¢/item; no connect time; $84 +$8 connect; 30¢ per item on or off line
~~DIS (89)~~, SDC

This geological reference database, produced by the American Geological Institute, provides coverage of the literature in about 30 different geoscience areas, including extraterrestrial geology, petrology, marine geology and geophysics. The file corresponds to several printed publications: Bibliography and Index of North American Geology (1961-70); Bibliography and Index of Geology Exclusive of North America (1967-68); Geophysical Abstracts (1966-71); Bibliography of Theses in Geology (1965-66); and Bibliography and Index of Geology (1969-present).

METEOROLOGICAL AND GEOASTROPHYSICAL ABSTRACTS, 1972-present, irregular updates.
DIS (29)

Corresponding to the printed publication of the same name, this database provides English-language abstracts for the most important meteorological and geoastrophysical research published in worldwide literature sources. The subjects of physical oceanography, hydrosphere/hydrology, environmental sciences, and glaciology are covered as well.

OCEANIC ABSTRACTS, 1964-present, bimonthly updates.
DIS (28)

This database, as does its print counterpart, covers the literature of oceanography and marine related subjects, including geology, pollution, meteorology, coastal resources, mining, and law and regulations.

HEALTH SCIENCES

ALCOHOL USE AND ABUSE, 1968-present, monthly updates.
BRS

This database provides an index to literature covering alcoholism and the effects of alcohol on the body. It deals primarily with the evaluation of treatment, and chemically dependent female, family therapy, and the MMPI, with minor emphasis on the elderly and the adolescent. No print counterpart.

DRUG INFO, 1968-present, monthly updates.
BRS

The literature on drugs, their chemistry and effects on the body is covered in this database, which focuses on the educational, sociological and psychological aspects of alcohol and drug use/abuse. Monographs, journals, conference papers, instructional guides and films are included.

COMPREHENSIVE CORE MEDICAL LIBRARY, current file, irregular updates.
BRS

CCML includes the complete text of prominent reference works, textbooks, and journals in the fields of emergency, internal, and critical care medicine.

DRUG INFORMATION FULLTEXT, full text of current print products, quarterly updates.
BRS, DIS (229)

Produced by the American Society of Hospital Pharmacists, this database contains complete full text, evaluative monographs from the American Hospital Formulary Service and the Handbook of Injectable Drugs. Detailed information is provided on virtually every single-drug entity available in the U.S., including investigational drugs and intravenous infusion solutions as well as commercial drugs.

EPILEPSYLINE, 1945-present, monthly updates.
BRS

The online counterpart to Excerpta Medica's Epilepsy Abstracts, this database includes additional material on the experimental aspects of seizures and convulsions as well as clinical diagnostic and treatment information.

EXCERPTA MEDICA, 1974-present, weekly updates.
BRS, DIS (72,73,172,173)

This file covers, as does the printed title, the biomedical literature. Nursing, dentistry, psychology, and the paramedical professions, such as podiatry and optometry, are excluded, but coverage of articles on drugs and potential drugs is extensive and health-related sciences such as pollution control, forensic science and public health are included.

HAZARDLINE, current file, monthly updates.
BRS

Available in this database is regulatory, handling, identification, and emergency care information for over 3,000 substances. Included are descriptions of substances; permissible exposure levels; incompatibilities; requirements for protective clothing, respirator use, and medical surveillance; symptoms and first aid treatment; regulatory status (including court decisions); and procedures for handling spills and waste.

HEALTH AUDIO-VISUAL ONLINE CATALOG, 1960-present, biannual updates.
BRS

Based on the holdings of the health sciences libraries of participating Ohio medical schools, this database contains bibliographic records for audiovisual packages covering a wide range of subjects in medicine, nursing, psychology, and allied health.

HEALTH PLANNING AND ADMINISTRATION, 1974-present, monthly updates.
BRS

The printed Hospital Literature Index is produced from this database, which contains information from journals, books, and technical reports on health care planning, facilities, organization, financing, management, manpower, and related subjects.

HSELINE, 1977-present, monthly updates.
PIL

This database covers the health and safety aspects of manufacturing industries, agriculture, production, occupational hygiene, explosives, engineering, mining, nuclear technology, and industrial air pollution.

INTERNATIONAL PHARMACEUTICAL ABSTRACTS (IPA), 1970-present, bimonthly updates.
BRS, DIS (74)

The IPA file, which corresponds to the printed title, covers information on the pharmaceutical profession and the development and use of drugs. Coverage ranges from clinical, practical and theoretical to the economic and scientific aspects of the literature.

IRCS MEDICAL SCIENCE DATABASE, 1982-present, semi-monthly updates.
BRS

Corresponding to the printed IRCS Medical Science, this database contains the full text of 32 specialist English language journals covering the entire field of medical and biomedical science.

MEDLINE (MEDLARS), 1966-present, monthly updates.
BRS, DIS (152, 153, 154)

Corresponds to the printed Index Medicus, Index to Dental Literature and International Nursing Index and covers all types of medical literature, including psychiatry and pharmacology. Additional materials not published in Index Medicus are included in the MEDLINE database in the areas of communication disorders, and population and reproductive biology. Only journals are indexed since 1981.

MEDOC, 1976-present, quarterly updates.
BRS

This file provides access to government documents in the health sciences.

NURSING & ALLIED HEALTH, 1983-present, bimonthly updates.
DIS (218)

This database indexes virtually all English-language nursing journals, publications of the American Nurses' Association, and the National League for Nursing, as well as primary journals in allied health areas such as cardiopulmonary technology; emergency services; health education; health sciences librarianship; medical, laboratory, and radiologic technology; the medical assistant; medical records; occupational, physical, and respiratory therapy; rehabilitation, and social service in health care.

PHARMACEUTICAL NEWS INDEX (PNI), 1974-present, monthly updates.
BRS, DIS (42)

This database covers the following industry newsletters to provide information about the pharmaceuticals industry, cosmetics, medical devices and related health fields: FDC Reports (The Pink Sheet); Drug Research Reports (The Blue Sheet); Medical Devices, Diagnostics and Instrumentation Reports (The Gray Sheet); Weekly Pharmacy Reports (The Green Sheet): Quality Control Reports (The Gold Sheet); PMA Newsletter; and Washington Drug and Device Letter.

POPULATION BIBLIOGRAPHY, 1966-present, bimonthly updates.
DIS (104)

Although more coverage is given to socioeconomic aspects, biomedical aspects of population, abortion, demography, family planning, fertility studies and population research area also covered. Journals, monographs, technical reports, government documents, conference proceedings, dissertations and unpublished reports are included; emphasis is on developing countries and the United States.

PRE-MED, current 3-4 months, weekly updates.
BRS

This is a current database in which citations are indexed previous to their appearance in MEDLINE. Citations from 108 core journals in clinical medicine, nursing, psychiatry, and hospital literature appear in PRE-MED within 10 days of their arrival in MEDLINE until 4-12 weeks following their publication. The PRE-MED file closes this information gap.

TELEGEN, 1973-present, monthly updates.
DIS(238)

This file provides access to information related to biotechnology and genetic engineering. It corresponds to the print publication Telegen Reporter.

PATENTS AND TRADEMARKS

*CLAIMS/CITATION, 1947-present, quarterly updates.
DIS (220,221,222)

This database can be used to search both forward and backward from a known reference or key patent to find cited references. Included are U.S. patent numbers back to 1947, the patent references cited against each patent during prosecution, and the numbers of the patents in which it has subsequently been cited. Patent topics covered include chemistry, engineering, nuclear science, science and technology.

*CLAIMS/CLASS, current file, annual replacement.
IDS (124)

Intended for use in conjunction with the CLAIMS/CHEM and CLAIMS/U.S. PATENTS files, this database is a classification code and the title dictionary for all classes and selected subclasses of the U.S. Patent Calssification System.

*CLAIMS COMPOUND REGISTRY, 1950-present, annual updates.
DIS (242)

This is a dictionary-type, non-bibliographic file containing records for specific chemical compounds. It is designed for locating compounds of interest for further searching in the CLAIMS UNITERM patent files (DIS-223,224,225). Each record contains the IFI compound number and name, synonyms, molecular formula, element count, fragment codes, and corresponding fragment terms.

*CLAIMS/UNITERM, 1950-present, monthly updates.
DIS (223,224,225), SDC

These files cover all U.S. chemical patents issued from 1950 to the present, all mechanical and electrical patents issued since 1963, and all design patents issued since 1980.

*CLAIMS/U.S. PATENT ABSTRACTS WEEKLY, current month only, weekly updates.
DIS (125)

These databases contain chemical, electrical, mechanical, and design patents announcedin the Official gazette of the U.S. Patent Office. Foreign equivalents from Belgium, France, Great Britain, West Germany, and the Netherlands are included.

*CLAIMS/U.S. PATENT ABSTRACTS, 1971-present, monthly updates.
DIS (24,25)

*CLAIMS/U.S. PATENT ABSTRACTS WEEKLY, current month only, weekly updates.
DIS (125)

*CLAIMS/U.S. PATENTS, 1950-1970, closed file.
DIS (23)

These databases contain all patents listed in the general, chemical, electrical and mechanical sections of the Official Gazette of the U.S. Patent Office.

*COMPUTERPAT, 1942-present, weekly updates.
PIL

This database contains abstracts and bibliographic data for all U.S. digital data processing patent documents as classified by the U.S. Patent and Trademark Office in subclasses 364/200 and 364/900.

*INPADOC, 1968-present, weekly updates.
PIL

This international patent database is the only database which contains bibliographic citations to patent documents issued by 52 national and regional Patent Offices.

*PATCLASS, 1836-present, semiannual updates.
BRS

A companion file to PATSEARCH, this file is used to retrieve U.S. Patent Classification Classes and Subclasses which appear together, or to determine what class and subclass codes have been assigned to a particular patent.

*PATDATA, 1975-present, weekly updates.
BRS

Citations and abstracts for U.S. patents issued in all technological categories are available through this database. Utility patents, reissue patents, and defensive publicatons are included.

*PATLAW, 1967-present, monthly updates.
PIL

This file provides comprehensive coverage of court and administrative rulings on intellectual property law. It is based on The United States Patents Quarterly (USPQ), a comprehensive reporting service containing the full text of reported judicial and administrative decisions relating to patents, trademarks, copyrights, and unfair competition. PATLAW contains the USPQ citations and headnotes (abstracts) for all decisions published in USPQ since 1967.

*PATSEARCH, 1971-present, weekly updates.
BRS, PIL

All utility patents issued by the U.S. Patent and Trademark Office since 1971 are included here, with all reissue patents issued since July 1975, all defensive publications since Dec. 1976, and all design patents issued since Jan. 1977. All Patent Cooperation Treaty (PCT) published patent applications from the World Intellectual Property Organization are also included.

TRADEMARKSCAN, 1884-present, weekly updates.
DIS(226)

The first online trademark screening tool, this database provides access to all active registered and pending trademarks on file in the U.S. Patent and Trademark Office. Each record contains the trademark and its U.S. class number, the owner name, a description of the goods or services the mark presents, and other informaiton about the status of the mark.

PHYSICAL SCIENCES

*CHEMICAL ABSTRACTS, 1967-present, biweekly updates.
BRS, DIS (308,309,310,311,320), PIL, SDC

This file corresponds to the printed Chemical Abstracts and provides access to the technical literature for chemistry, chemical engineering, macromolecular and physical and analytical chemistry.

COMPENDEX, 1970-present, monthly updates.
BRS, DIS (8), PIL, SDC

The computerized Engineering Index is the machine-readable version of the Engineering Index which covers the significant engineering literature of the world. Journals, publications of societies, proceedings and government reports are included; subjects covered include materials' properties and testing, fluid flow, heat and thermodynamics, light and optical technology, sound and acoustical technology, and engineering physics.

*INSPEC, 1969-present, monthly updates.
BRS, DIS (12,13), SDC

This database, which covers all areas of pure and applied physics, is the machine-readable counterpart of three abstracting journals: Physics Abstracts, Electrical and Electronics Abstracts and Computer and Control Abstracts. Journal articles and, to a lesser extent, government reports, patents and monographs are included to provide information in such areas as atomic and molecular physics, and elementary particle physics.

MASS SPECTROMETRY BULLETIN, 1966-present, monthly updates.
PIL

Available through this file are bibliographic citations to documents in the field of mass spectrometry and allied subjects such as instrument design and techniques; isotopic analysis, chemical analysis, organic chemistry, atomic and molecular processes, surface phenomena and solid state studies, thermodynamics and reaction kinetics.

SPIN, 1975-present, monthly updates.
DIS (62)

SPIN (Searchable Physics Information Notices) covers all major areas of physics, emphasizing American and Russian physics research. Subjects covered include elementary particles, atomic and molecular physics, fluids plasmas, materials science, physical chemistry, and such related areas as geophysics, astrophysics, biophysics and biomedical engineering.

TECHNOLOGY

FOODS ADLIBRA, 1974-present, monthly updates.
DIS (79)

This database covers new developments in food technology and packaging, including information on the food industry, nutrition, research in processing methods and packaging, government guidelines and regulations, marketing and statistics. Some U.S. and British patents are also included.

*FSTA, 1969-present, monthly updates.
DIS (51)

FSTA (Food Science and Technology Abstracts) covers research and new development literature in areas related to food science and technology, including agriculture, biochemistry, engineering, and home economics. It indexes journals, patents, and books, as does the printed version.

FROST AND SULLIVAN DM2, 1975-present, quarterly updates.
DIS (59)

This database provides information about U.S. Government contract awards, request-for-proposals, planning estimates, R & D sources sought, and advanced planning procurement information for the engineered systems market. It covers fields such as aircraft, communications, data processing, missiles and space, and basic research.

*PAPERCHEM, 1969-present, monthly updates.
DIS(240),SDC

Abstract Bulletin of the Institute of Paper Chemistry is the printed counterpart of this file, which covers the scientific and technical literature that deals with the theoretical principles, technologies, raw materials, products and practices of the pulp, paper and board manufacturing and utilizing industries.

PIRA, 1975-present, monthly updates.
PIL

The PIRA file is the online counterpart of four abstracting journals: Paper and Board Abstracts, Printing Abstracts, Packaging Abstracts and Management and Marketing Abstracts. It is useful for information in the field of paper and board mills and manufacturing, printing, photography, bookbinding, packaging and shipping materials, advertising, retailing and industrial relations.

RAPRA ABSTRACTS, 1972-present, monthly updates.
PIL

Rubber and Plastics Research Association Abstracts covers the commercial, technical and research aspects of the rubber and plastics industry. It includes information on materials (including synthesis and polymerization), processing technology, applications of polymers, toxicity reports, economic and commercial information.

STANDARDS & SPECIFICATIONS, 1950 or earlier to present, monthly updates.
DIS (113)

This file provides titles and descriptive information for government and industry standards, specifications, and related documents which specify terminology, performance testing, safety, materials, products or other requirements and characteristics of interest to a particular technology.

TEXTILE TECHNOLOGY DIGEST, 1978-present, monthly updates.
DIS(119)

International coverage of the literature of textiles and related subjects is the focus of this database. Included are the various aspects of textile production and processing, automation and management of operations, testing and measurement, cleaning, design and finishing, surgical products, geotextiles and composites, home economics, marketing and quality control, dyes and resins, chemicals and carcinogens, etc.

*WELDASEARCH, 1967-present, monthly updates.
DIS (99)

The WELDASEARCH database provides coverage of the international literature on all aspects of the joining of metals and plastics and related areas such as metals spraying and thermal cutting. Information is extracted from several thousand journals, research reports, books, standards, patents, theses and special publications.

*WORLD ALUMINUM ABSTRACTS, 1968-present, monthly updates.
DIS (33)

This file, whose printed version has the same title, provides coverage of the world's technical literature on aluminum, from ore processing through end use. Journals, patents, conference proceedings, government reports, books and dissertations are covered.

WORLD SURFACE COATINGS ABSTRACTS, 1976-present, monthly updates.
PIL

This database covers patents, journal articles and standards in the fields of paint and surface coating technology and related subjects. Included are topics such as legislation, marketing and management, storage, transport, analytical methods, testing, optical properties, industrial hazards, statistics, etc.

*WORLD TEXTILES, 1970-present, monthly updates.
DIS (67)

This database is the machine-readable version of World Textile Abstracts and covers the world literature on the science and technology of textile and related materials; technical economics, production, and management of the textile industry; and on the consumption of an international trade in textile materials and products.

VOL. 2 - NO. 2 GEOTHERMICS JUNE 1973

International Journal of Geothermal Research

A Five-Component Magneto-telluric Method in Geothermal Exploration: the M.T.-5-E.X.

LOUIS MUSÉ *

ABSTRACT

The present paper describes a new method designed both at recording and processing levels for a practical solution of the overall problem of the Earth electromagnetism, in geophysics.

Up to now, the random character of the natural signals prevented any measurement of reliable values of the phase shift between the various electromagnetic components at a given place. Hence it is impossible numerically to solve the general linear relations binding these components simply by using the processes of the standard harmonic analysis.

In order to overcome this difficulty the writer designed an analysis method based on a hypothesis according to which the natural signals are considered as real exponential functions increasing with time.

The writer, thus, was able to work out systematically a magneto-telluric prospection method utilizing the five standard electromagnetic components quantitatively, and in particular the vertical magnetic component.

The application of this method — named the M.T.-5-E.X. — to geothermal prospection in Italy in the region of Travale (Tuscany) obtained various practical results of particular interest. They will be described in a paper which will be edited jointly with the researchers of the International Institute for Geothermal Research of Pisa (Italy).

Introduction

Electromagnetic methods in geothermal prospection are of considerable importance since the responses obtained by means of these methods are determined by factors which are directly linked to the presence of geothermal zones.

As it is pretty well known, geothermal zones are those zones where the electrical conductivity becomes particularly high. Now, the electromagnetic phenomena in general are the most sensitive to the presence of such conductive media.

It is not surprising therefore that the magneto-telluric method has already been tested in geothermal exploration.

Up to now, however, considerable difficulties were encountered when having to obtain by means of this method information which could be employed in the exploration and the exploitation of geothermal fields.

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A new magneto-telluric method is now proposed which involves a new process of data recording and analysis. It can be applied to objectives of complex geometry.

This method is called the Five-Component Magneto-telluric Method with Exponential Solutions (abbreviated to M.T.-5-E.X.). It renders possible a detailed prospecting based on a very close network of recording stations.

Thus it should be possible to bring to light contrasts in resistivities whatever the depths may be and facilitate the detection and interpretation of areas which, within a field, have different significances from a geothermal point of view.

To put this to the test, the proposed method was applied in an area which is now, and will be in the future, the subject of much research, having shown itself very promising from a productive point of view.

Basic principles of the traditional magneto-telluric method

It is important to begin by reviewing the principles underlying magneto-telluric prospecting (M. T.).

Natural electric currents, called telluric currents, circulating in the ground are known to undergo continuous fluctuations. The earth's magnetic field is also known to react in the same manner.

Yet the fluctuations of the telluric currents and those of the magnetic field are not independent of one another. Generally speaking, the variations occurring in the three components of the magnetic field and in the two horizontal components of the telluric field are linked in a relatively complicated manner, but which always remains quantitative, through the laws of electromagnetism.

As these relations depend on the electric conductivity of the underground, they make it possible to determine this conductivity. The aforesaid natural electromagnetic variations do not have the characteristic of harmonic variations, but are of great complexity. It may be postulated however that they result from the superimposition of harmonic variations of different periods. More precisely it may be said that the spectrum of the magnetic variations, and also that of the corresponding telluric variations, are more or less continuous spectra, whence it is possible to extract almost any period T by means of appropriate filtering. It is felt therefore that the geophysicist may be led to use Fourier transforms to analyse the natural electromagnetic variations.

But, in fact, these natural electromagnetic variations, as mentioned above, are random phenomena, and it will be shown in the following that any analysis-tool in magneto-telluric, when based on the hypothesis that natural electromagnetic variations are harmonic, is limited in practice to the case of the horizontal layered half space.

Characteristics and limitations of the harmonic analysis method

A brief review follows of the basic concepts used in the traditional magneto-telluric method. This problem has been handled by several authors such as CAGNIARD (1953), BERDICHEWSKI (1968), THIKONOV (1950), RIKITAKE (1966). In this section the reader is referred to the publication by CAGNIARD.

Homogeneous half space

Let us assume a homogeneous half space in which the rectangular coordinates x and y are on the flat ground surface and the axis z is the downward positive vertical. Let us consider a schematic and ideal sheet of telluric current, which we shall suppose to be uniform, harmonic of period T, flowing in the electrically homogeneous medium of conductivity σ. If the harmonic sheet flows along x, the components of the Hertz vector $\Pi\ (t)$ along y, z are nil. Furthermore, $\Pi\ (t)$ depends only on z and on t.

$$\Pi\ (t) = \Pi_x e^{-i\omega t}$$

where t is time.

And therefore the electric and magnetic fields are

$$E\ (t) = E_x\ e^{-i\omega t}$$
$$H\ (t) = H_y\ e^{-i\omega t}$$

The factor $e^{-i\omega t}$ will be understood in the following rather than expressed explicitly.

Referring to the quite long periods T generally used in M.T., Maxwell's equations are satisfied if

$$\nabla^2 \Pi_x + 4\pi\sigma\omega i \Pi_x = 0 \tag{1}$$

In general, the electric field $\mathscr{E}(t)$ and magnetic field $\mathscr{H}(t)$ are expressed by:

$$\left.\begin{aligned} \mathscr{E}(t) &= \text{grad div } \Pi\ (t) - \nabla^2 \Pi\ (t) \\ \mathscr{H}(t) &= 4\pi\sigma \text{ curl } \Pi\ (t) \end{aligned}\right\} \tag{2}$$

and in the present case by

$$\left.\begin{aligned} E_x &= 4\pi\sigma\omega i \Pi_x & E_y &= E_z = 0 \\ H_y &= 4\pi\sigma \frac{\partial \Pi_x}{\partial z} & H_x &= H_z = 0 \end{aligned}\right\} \tag{3}$$

As in this case E_x is proportional to Π_x, we can choose E_x as the Hertz vector, so that

$$\left.\begin{aligned} \frac{\delta^2 E_x}{\delta z^2} + 4\pi\sigma\omega\ i\ E_x &= 0 \\ H_y = -\frac{i}{\omega} \frac{\delta E_x}{\delta z} & \end{aligned}\right\} \tag{4}$$

Owing to (4), E_x and H_y must be in the form

$$\left.\begin{aligned} E_x &= Ae^{a\sqrt{\sigma}z} + Be^{-a\sqrt{\sigma}z} \\ H_y &= e^{i\frac{\pi}{4}} \sqrt{2\sigma T} \left[-Ae^{a\sqrt{\sigma}z} + Be^{-a\sqrt{\sigma}z}\right] \end{aligned}\right\} \tag{5}$$

A and B representing two arbitrary constants and a being defined as

$$a = 2 \frac{\pi}{\sqrt{T}} (1 - i)$$

In the case of a half space the terms with positive exponents equal zero, so we have

$$\left.\begin{aligned} E_x &= Be^{-a\sqrt{\sigma}z} \\ H_y &= Be^{i\frac{\pi}{4}} \sqrt{2\sigma T}\ e^{-a\sqrt{\sigma}z} \end{aligned}\right\} \tag{6}$$

At ground level ($z = 0$)

$$\left.\begin{aligned} E_x &= B \\ H_y &= Be^{i\frac{\pi}{4}} \sqrt{2\sigma T} \end{aligned}\right\} \tag{7}$$

We should also remember a term which is used constantly, that is the « depth of penetration » p, at which the fields' amplitudes are restricted to the fraction $1/e$ of the ground level value. When using the practical units below

$$p = \frac{1}{2\pi} \sqrt{10 \varrho T}$$ skin depth

Layered half space

The half space now has to be considered as being divided up into homogeneous layers by planes $z_j = \sum_{i=1}^{j} h_i$ (where $z = 0$ is the ground level), h_j is the thickness of the j-th layer, while the thickness of the deepest layer is assumed to be ∞. By σ ($j = 1, 2, \ldots n$) we denote the conductivity of the media forming the layer $\left(\sigma_j = \frac{1}{\varrho_j}\right)$.

As we must assure the continuity of the electric and the magnetic fields at the different interfaces, we obtain recurrent relations yielding the values E_x and H_y at ground level

$$E_x = M\, e^{-i\varphi}$$

$$H_y = \sqrt{2\sigma T}\; N\, e^{i\left(\frac{\pi}{4} - \psi\right)}$$

where M, N values and angles φ, ψ are suitably evaluated.

Note that the phase shift of H_y with respect to E_x is $\left(\frac{\pi}{4} + \varphi - \psi\right)$.

The well-known relation is obtained for the apparent resistivity

$$\varrho_a = \varrho_1 \left|\frac{M}{N}\right|^2 \tag{8}$$

However, we can agree that the modulus of the ratio $\frac{E_x}{H_y}$ is equal to $\frac{1}{\sqrt{2\sigma_a T}}$ in which σ_a would be the conductivity of a homogeneous formation which would give the same modulus of the ratio between fields whose value has been observed experimentally. The quantity $\sigma_a = \frac{1}{\varrho_a}$ is, by definition, the apparent conductivity, and

$$\varrho_a = 0.2\, T \left|\frac{E_x}{H_y}\right|^2 \tag{9}$$

The pratical units are as follows

$\rho = \frac{1}{\sigma}$ is expressed in ohm · meter (Ω m);

T, is expressed in seconds (s);

E_x, is espressed in millivolt/kilometer (mV/km);

H_y, is expressed in gamma (γ).

In other words, after having carried out an M. T. recording in a region characterized by a tabular resistivity - depth distribution, and after having proceeded with a harmonic analysis of the electric- and magnetotelluric signals, the modulus of the ratio $\frac{E_x}{H_y}$ and the phase shift with respect to T can be obtained. This is achieved by analogical or mathematical filtering or directly by Fourier transforms.

In theory, the knowledge of the modulus of the ratio $\frac{E_x}{H_y}$ for a given period T is sufficient to obtain the value of the corresponding phase shift. Unfortunately, as experience shows, the precision offered by any harmonic analysis for obtaining moduli of the ratio $\frac{E_x}{H_y}$ is quite insufficient to calculate the aforesaid phase shift with the required accuracy. For the same reason, it is all the more difficult to measure reliable and repetitive phase shifts from the M. T. recordings. As mentioned earlier, this is due to the random character of these phenomena. In application, we can only obtain experimentally the modulus of ratio $\frac{E_x}{H_y}$ with an unsatisfactory accuracy, particularly when noise affects recordings.

depth of penetration ≡ p, field ampl = $1/e$

$$p = \frac{1}{2\pi}\sqrt{10\rho T} = \frac{1}{2\pi}\sqrt{10\rho/f}$$

$$p = .503\sqrt{\rho/f}$$

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analysis prevents practical use of the phase differences. It becomes thoroughly impossible to solve equation systems of the type (10), and consequently it is impossible to use the vertical magnetic component quantitatively.

Theoretical concept of M.T.-5-E.X.

When it is understood that in practice it is impossible to measure the phase differences between the various electromagnetic natural components, it is then necessary to find another method without using these phase differences.

To this end, a solution to Maxwell's equations in the form of real exponentials will be considered.

To solve (2) it is enough to introduce solutions of the type

$$\Pi(t) = \Pi e^{\frac{t}{\tau}}, \quad H(t) = He^{\frac{t}{\tau}}, \quad E(t) = Ee^{\frac{t}{\tau}}$$

in which τ is real and positive. The time constant τ in this method is comparable to the period T in harmonic analysis.

It should be noted that *the solutions under exponential form* are not justified as a true representation of the natural electromagnetic variations, but *are a mathematical tool*, which avoids the difficulty of obtaining the phase difference.

Homogeneous half space

In this section, information will be given on the consequences related to apparent resistivity and depth of penetration for the homogeneous half space, according to the assumed hypotheses.

The relations previously computed on the basis of a harmonic hypothesis, will now be recomputed with the exponential solutions. All the other features of the telluric current sheet remain. The equation (1) becomes

$$\nabla^2 \Pi_x - \frac{4\pi\sigma}{\tau} \Pi_x = 0 \qquad (11)$$

and

$$\left.\begin{aligned} H_y &= 4\pi\sigma \frac{\partial \Pi_x}{\partial z} \qquad & H_x &= H_z = 0 \\ E_x &= -\frac{4\pi\sigma}{\tau} \Pi_x \qquad & E_y &= E_z = 0 \end{aligned}\right\} \quad (12)$$

Owing to our exponential solution scheme we obtain

$$E_x = Ae^{a\sqrt{\sigma}\, z} + Be^{-a\sqrt{\sigma}\, z}$$

$$H_y = 2\sqrt{\pi\sigma\tau}\left[-Ae^{a\sqrt{\sigma}\, z} + Be^{-a\sqrt{\sigma}\, z}\right]$$

with

$$a = 2\sqrt{\frac{\pi}{\tau}}$$

The term with an increasing exponential has no physical meaning in the case of a medium with infinite thickness. Therefore, dropping the B constant, one has

$$E_x = e^{-2\sqrt{\frac{\pi\sigma}{\tau}}\, z}$$

and

$$H_y = 2\sqrt{\pi\sigma\tau}\; e^{-2\sqrt{\frac{\pi\sigma}{\tau}}\, z}$$

We find the resistivity in practical units

$$\rho = 0.4\,\pi\tau \left[\frac{E_x}{H_y}\right]^2$$

while for the depth of penetration p one has

$$p = \frac{1}{2\sqrt{\pi}} \sqrt{10\,\rho\tau}$$

$$= \frac{1}{2\sqrt{\pi}} \sqrt{\frac{10\rho}{f}} = .892 \sqrt{\rho t}$$

Layered half space

In the case of several horizontal layers, each having a different conductivity, the apparent resistivity is introduced exactly the same as in the harmonic case, with a recurrent expression for each interface. These expressions contain only real numbers and consequently the computations are half as long as in the harmonic case. The following expression for apparent resistivity is obtained

$$\rho_a = 0.4\,\pi\tau \left[\frac{E_x}{H_y}\right]^2$$

General case

In the general case and when the source is considered at the infinite, whatever the structure of the underground may be, the five electromagnetic components at ground level are related by constant parameters independent of time t but function of the time constant τ. The same expressions are obtained (10) as in the harmonic hypothesis, but E_x, E_y, H_x, H_y, H_z, and a, b, c, d, g, h, are now real expressions. One is then able to compute the apparent resistivity in any direction after a rotation of the axis. In other words, it is possible to consider the case of cylindrical or near-cylindrical structures by using simple computation.

Let us assume that the coordinate system used is defined by our pick-up devices on the ground: that is, we are recording the several electric and magnetic components along the axes OX, OY, OZ. Let Θ be the angle at the surface between the parallel OX' to the cylindrical or near-cylindrical structure axis and the OX axis (Figure 1).

After rotation Θ, we can write

$$E_x = E_{x'} \cos\Theta - E_{y'} \sin\Theta$$

$$E_y = E_{x'} \sin\Theta + E_{y'} \cos\Theta$$

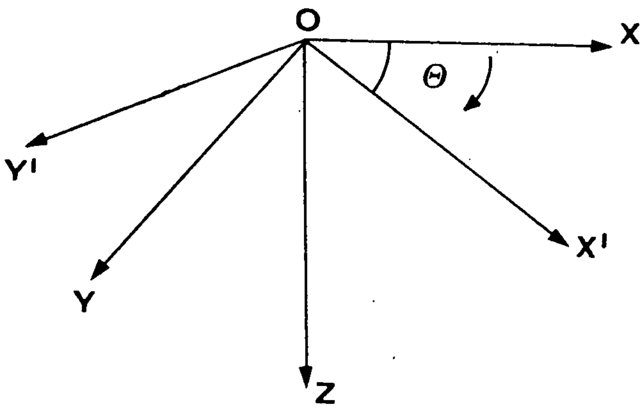

FIG. 1

and, by remembering (10), we obtain H_z

$$H_z = E_{x'} [g\cos\Theta + h\sin\Theta] + E_{y'} [h\cos\Theta - g\sin\Theta]$$

If the telluric sheet is parallel to the axis of the cylinder, H_z generally does not equal zero (except for symmetrical cases which do not happen in nature) but the contribution of E_y' equals zero. Consequently we obtain

$$g \sin\Theta = h \cos\Theta$$

In other words, the direction of axis OX′ is given by

$$\tan\Theta = \frac{h}{g} \qquad (13)$$

Knowing Θ, as mentioned above, it is easy to compute the various following apparent resistivities after rotation of the axis. The direction given by Θ will be called « longitudinal direction » or in more geological terms « main trend ».

Other results may then be obtained

apparent longitudinal resistivity (along the axis OX′)

$$= 0.4\,\pi\tau \left[\frac{E_{x'}}{H_{y'}}\right]^2 = 0.4\,\pi\tau \left[\frac{g^2 + h^2}{cg^2 - bh^2 + (d-a)\,gh}\right]^2$$

apparent transversal resistivity (along the axis OY′)

$$= 0.4\,\pi\tau \left[\frac{E_{y'}}{H_{x'}}\right]^2 = 0.4\,\pi\tau \left[\frac{g^2 + h^2}{bg^2 - ch^2 + (d-a)\,gh}\right]^2$$

apparent longitudinal residual resistivity

$$= 0.4\,\pi\tau \left[\frac{E_{x'}}{H_{x'}}\right]^2 = 0.4\,\pi\tau \left[\frac{g^2 + h^2}{ag^2 + dh^2 + (b+c)\,gh}\right]^2$$

apparent transversal residual resistivity

$$= 0.4\,\pi\tau \left[\frac{E_{y'}}{H_{y'}}\right]^2 = 0.4\,\pi\tau \left[\frac{g^2 + h^2}{ag^2 + dh^2 - (b+c)\,gh}\right]^2$$

apparent vertical resistivity

$$= 0.4\,\pi\tau \left[\frac{E_x}{H_z}\right]^2 = \frac{0.4\,\pi\tau}{g^2 + h^2}$$

Thus, the use of the quantitative variations of the vertical magnetic component is very important since it enables to determine the longitudinal direction Θ and all the set of resistivities shown above. The physical meaning of these quantities and their application in geothermal prospection will be shown later on. However, it should be noted that, as long as there is a high enough value of H_z a direction will always be found, whether the considered case is cylindrical or not. The criteria for the cylindrical case are given by the « apparent residual longitudinal resistivity » or by the « apparent residual transversal resistivity », which in this case must be infinite or at least very large.

Some applied aspects of M.T.-5-E.X.

As mentioned above, natural electromagnetic variations are no more harmonic than exponential. In either case, it is necessary to construct solutions corresponding to the type of analysis chosen. The following will show what the various conditions are, under which the exponential type solution may be used, and how exponential type solutions solving Maxwell's equations may be easily determined from field recordings.

Exponential type solution to Maxwell's equations, constructed from the output signal of a magnetic sensor

Some words will be given to an illustration of a number of topics related to the magnetic sensor. Such a sensor consists of an air or magnetic cored coil with a convenient number of turns.

This winding may be represented by the simple circuit of Figure 2, regardless of its shape or its complexity. One emphasises that the capacity C is either the distributed capacity of the coil, or the distributed capacity plus an external capacity added in order to create resonance effects favourable to an increased sensitivity in certain regions of the spectrum.

Let this circuit (Figure 3) be placed at the input of an amplifier and recorder. The input impedance of the amplifier being ξ, this may be assumed to be a pure resistance to simplify the discussion. If the coil is energized by the magnetic field H (x, y, z, t), in abbreviation H (t), the current i flowing through ξ is given by

$$L \xi C \frac{d^2 i}{dt^2} + (\xi RC + L) \frac{di}{dt} + (R + \xi) i = - \chi \frac{\partial H(t)}{\partial t} \tag{14}$$

with

$$\chi = \mu_a N S$$

μ_a = apparent permeability of the core;

N = number of turns of the coil;

S = surface of the mean turn of the coil.

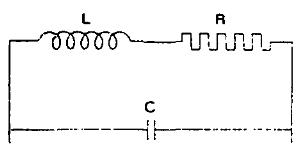

FIG. 2

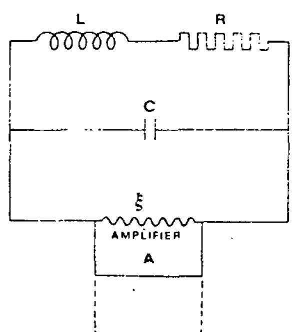

FIG. 3

This relationship, which involves a second order differential equation, only concerns the spectrum of usual magnetic variations utilized in geothermal prospection and characterized by slow variations. Under this restriction, the output tension of the amplifier is defined as:

$$U = \xi i$$

the constant K of amplification being understood.

Instant t being taken as time origin until which i equals zero, we write

$$\xi I \subset \xi i$$

ξ I is the Laplace transform of the tension ξ i, function of time t. Now, I is expressed by

$$I = \left[\frac{i_{(t=0)} \left[\frac{L\xi C}{\tau} + (\xi RC + L) \right] + L\xi C \frac{di}{dt}_{(t=0)}}{\Xi} - \frac{\chi}{\Xi} \int_0^\infty e^{-\frac{t}{\tau}} \frac{\partial H(t)}{\partial t} dt \right]$$

by taking

$$\Xi = \frac{L\xi C}{\tau^2} + \frac{(\xi RC + L)}{\tau} + (R + \xi)$$

It is obvious that when

$$i_{(t=0)} = 0 \text{ and } \frac{di}{dt}_{(t=0)} = 0$$

one has

$$I = - \frac{\chi}{\Xi} \int_0^\infty e^{-\frac{t}{\tau}} \frac{\partial H(t)}{\partial t} dt$$

Now, we go back to Maxwell's equations to find out the conditions under which expression $Ie^{\frac{t}{\tau}}$ is a Maxwell's solution. Being any electromagnetic magnitude, X should verify the equation

$$\nabla^2 X - \frac{4\pi}{\rho} \frac{\partial X}{\partial t} = 0 \tag{15}$$

being understood that X = (x, y, z, t).
Let's consider the expression

$$Y = e^{\frac{t}{\tau}} \int_0^\infty e^{-\frac{t}{\tau}} \frac{\partial X}{\partial t} dt$$

The requirements for Y to be a solution of (15) are now considered from

$$Y = e^{\frac{t}{\tau}} \left[\frac{1}{\tau} \int_0^\infty e^{-\frac{t}{\tau}} X dt - X_{(t=0)} \right]$$

Thus

$$\nabla^2 Y = e^{\frac{t}{\tau}} \left[\frac{1}{\tau} \int_0^\infty e^{-\frac{t}{\tau}} \nabla^2 X \, dt - \nabla X_{(t=0)} \right]$$

On the other hand

$$\frac{\partial Y}{\partial t} = \frac{e^{\frac{t}{\tau}}}{\tau} \int_0^\infty e^{-\frac{t}{\tau}} \frac{\partial X}{\partial t} dt$$

If one brings $\nabla^2 Y$ and $\frac{\partial Y}{\partial t}$ into (15), the latter becomes

$$e^{\frac{t}{\tau}}\left[\frac{1}{\tau}\int_0^{\infty} e^{-\frac{t}{\tau}}\nabla^2 X\, dt - \nabla^2 X_{(t=0)}\right.$$

$$\left. - \frac{4\pi}{\varrho}\frac{1}{\tau}\int_0^{\infty} e^{-\frac{t}{\tau}}\frac{\partial X}{\partial t}\, dt\right] = 0$$

or briefly

$$e^{\frac{t}{\tau}}\left[\frac{1}{\tau}\int_0^{\infty} e^{-\frac{t}{\tau}}\left(\nabla^2 X - \frac{4\pi}{\varrho}\frac{\partial X}{\partial t}\right) dt - \nabla^2 X_{(t=0)}\right] = 0$$

The term $\nabla^2 X - \frac{4\pi}{\varrho}\frac{\partial X}{\partial t}$ which is present under the integral symbol, equals zero by definition, since X is an electromagnetic magnitude. In this particular case it becomes necessary that

$$\nabla^2 X_{(t=0)} = 0$$

or otherwise, since (15) must be verified, that

$$\frac{\partial X}{\partial t}_{(t=0)} = 0$$

In other words, the expression $\xi\, I e^{\frac{t}{\tau}}$ will be a Maxwell's solution, provided that $\frac{\partial X}{\partial t}_{(t=0)}$ is equal to zero.

Besides, equation (14) gives the relation

$$(R+\xi)\, i_{(t=0)} + \frac{di}{dt}_{(t=0)}(\xi RC + L) + L\xi C\, \frac{d^2 i}{dt^2}_{(t=0)}$$

$$= -\chi\, \frac{\partial H(t)}{\partial t}_{(t=0)}$$

Otherwise, if to the two conditions already expressed above one adds

$$\left.\begin{array}{ll} i_{(t=0)} = 0 & \frac{di}{dt}_{(t=0)} = 0 \\ \frac{d^2 i}{dt^2}_{(t=0)} = 0 & \end{array}\right\} \quad (16)$$

all the requested conditions are met and $I e^{\frac{t}{\tau}}$ actually is a solution of Maxwell's equation (15) since then $\frac{\partial H(t)}{\partial t}_{(t=0)}$ equals zero according to the condition $\frac{\partial X}{\partial t}_{(t=0)}$.

Construction of exponential type solutions from actual recordings

It is always possible to find a characteristic time as defined by the three conditions (16) in a recording from a single magnetic sensor along any axis. However, there is some difficulty in finding these three conditions satisfied simultaneously on the recordings from the three magnetic sensors energized by $H_x(t)$, $H_y(t)$, $H_z(t)$, respectively. Besides, the telluric recordings [$E_x(t)$, and $E_y(t)$] yielded by traditional telluric lines are a priori not justified in satisfying the conditions (16). Then, various adaptations of the recording device have to be made before exponential type solutions, as described above, may be constructed.

Adaptation of the recording device

Some adaptations of the recording device are briefly described in the following paragraph.

Let us assume that the three magnetic recording channels are of the above defined type and characterized by the response (14). By introducing a « distortion generator » into each telluric recording channel we obtain, between the output terminals of each aforesaid telluric recording channel, an output signal of the ξi type. ξ is input impedance of the amplifiers used in the telluric recording chains, and current i is linked to the variations of the electric component, for instance $E_x(t)$, by the following relation, with an approach at least equal to 10^{-2} in the used spectrum

$$L\xi C\, \frac{d^2 i}{dt^2} + (\xi RC + L)\, \frac{di}{dt} + (R+\xi)\, i = -K\, \frac{\partial E_x(t)}{\partial t}$$

with L, C, and R having the same value as those of physical components of the magnetic recorders. The five-component recordings then have to be processed all incoming from recording channels characterized by identical transfer functions, and identical transient responses to the energizing signals. The recording device so designed otherwise offers many practical advantages, and in particular eliminates all troubles of electrods-polarization on the telluric lines. It has been subject to various patents pending in several countries.

Now let's examine how it is possible, from records made by devices designed as described above, to elaborate exponential solutions in accordance with the conditions (16). Among other possible methods, experience proved that the simplest procedure is that which we shall call « the linear combination method », which the next paragraph will deal with.

Linear combination method

Assumption is made that the five-electromagnetic components are recorded according to the device described above. It is also assumed that the recordings which are thus obtained are digitalized on magnetic tape, and that the time constant τ considered is large enough with respect to the time spacing defined by the sampling rate.

On the records six arbitrary instants t_0, t_1, t_2, t_3, t_4, t_5, are selected: in practice it may be advantageous to tie up the order of magnitude of the time intervals determined by the instant t_i, to the considered τ. On each component of the record, each instant t_i corresponds to a sample labelled with an index n_i. Five arbitrary constants are then determined a_1, a_2, a_3, a_4, a_5, so that on each component $X(t)$ a relation of the following type is verified.

$$X(t_0) + a_1 X(t_1) + a_2 X(t_2) + a_3 X(t_3) + a_4 X(t_4) + a_5 X(t_5) = 0 \qquad (17)$$

By writing this relation for each component, we define a linear system of five equations. So the numerical value of the five constants mentioned above are calculated.

For each considered component one constructs a function of the type $U(t)$ by taking instant t_0 as the initial time, that is

$$U(\mathrm{t}) = X(t) + a_1 X(t+t_1) + a_2 X(t+t_2) + a_3 X(t+t_3) + a_4 X(t+t_4) + a_5 X(t+t_5) \qquad (18)$$

the function $U(t) = 0$ for $t \leq t_0$

Let us assume now that we have constructed six functions of the type (18) for each component. Every one of these six functions takes zero value until an origin instant that we shall call respectively

$$t_{0_1},\; t_{0_2},\; t_{0_3},\; t_{0_4},\; t_{0_5},\; t_{0_6}$$

corresponding respectively to the samples expressed above

$$n_1 \quad n_2 \quad n_3 \quad n_4 \quad n_5 \quad n_6$$

and are expressed by taking instant t_{0_1} as initial time

$$U_1(t),\; U_2(t+t_{0_2}),\; U_3(t+t_{0_3}),\; U_4(t+t_{0_4}),\; U_5(t+t_{0_5}),\; U_6(t+t_{0_6}),$$

Let us now consider the instant set defined on each component by the samples with the indexes

$$n_{1+1} \quad n_{2+1} \quad n_{3+1} \quad n_{4+1} \quad n_{5+1} \quad n_{6+1},$$

corresponding to instants that are respectively expressed by

$$t_{0_{1+1}},\; t_{0_{2+1}},\; t_{0_{3+1}},\; t_{0_{4+1}},\; t_{0_{5+1}},\; t_{0_{6+1}}.$$

The five constants α, β, γ, δ, η are now introduced in order to satisfy the following condition for each component

$$U_1(t_{0_{1+1}}) + \alpha U_2(t_{0_{2+1}}) + \beta U_3(t_{0_{3+1}}) + \gamma U_4(t_{0_{4+1}}) + \delta U_5(t_{0_{5+1}}) + \eta U_6(t_{0_{6+1}}) = 0$$

Now, by taking instant t_{0_1} as the initial time, we construct a function of the following type for each component

$$\Psi(t) = U_1(t) + \alpha U_2(t+t_{0_2}) + \beta U_3(t+t_{0_3}) + \gamma U_4(t+t_{0_4}) + \delta U_5(t+t_{0_5}) + \eta U_6(t+t_{0_6}) \qquad (19)$$

Functions of type (19) equal zero for $t \leq t_{0_{1+1}}$. We shall call them « linear second order combination ».

SOUNDING 83 - C.N.R. - TRAVALE - ITALY - 3.7.1973

NRAC	NE	DELAF	RATO	NTH	THETA	SIGTH	ROALON	ROATRA	ROALORES	ROATRARE	ROAVERT	ROX	ROY
116.	6370.	11111	8.000	—1 0	32.7	0.	105.7	156.4	10505.7	1421.1	329.9	57.8	282.6
116.	6370.	11111	7.071	—1 0	33.6	0.	90.4	135.1	18703.2	1341.5	296.5	48.6	247.0
116.	6370.	11111	6.000	0 0	33.4	0.	73.7	108.4	8448.4	1276.7	238.1	39.2	197.9
238.	9550.	11111	5.000	0 0	34.6	0.	65.6	95.9	3931.5	3463.6	281.0	38.5	181.7
238.	9550.	11111	4.000	11 9	33.9	—1.	51.6	67.6	2645.3	1277.3	181.1	29.0	126.6
235.	9550.	11111	3.162	28 16	34.5	—1.	40.8	48.9	2320.5	2585.8	157.8	22.1	92.0
250.	9820.	11111	2.646	41 21	32.7	—1.	38.2	49.5	1192.3	2263.4	109.0	20.7	87.2

SOUNDING 62 - C.N.R. - TRAVALE - ITALY - 1.7.1973

NRAC	NE	DELAF	RATO $\sqrt{\tau}$	NTH		THETA $\Theta°$	SIGTH	ROALON ρ_a longit	ROATRA ρ_a Trav.	ROALORES res.	ROATRARE res.	ROAVERT ρ_a vert.	ROX ρ_a X axis	ROY ρ_a Y axis
228.	6041.	11111	8.000	—1	0	56.9	0.	453.1	489.5	107918.3	37573.7	1976.2	710.9	315.3
228.	6041.	11111	7.071	—1	0	56.4	0.	382.4	405.4	52967.3	38051.5	1710.4	569.3	284.0
228.	6041.	11111	6.000	—1	0	55.4	0.	299.1	314.7	56171.6	36962.5	1367.7	432.6	246.7
250.	6411.	11111	5.000	1	1	56.7	1.	277.0	284.6	88086.7	53106.4	1126.4	356.9	220.6
249.	6401.	11111	4.000	9	6	56.7	1.	204.9	211.3	31009.2	11293.0	820.0	249.2	175.7
249.	6401.	11111	3.162	35	23	54.8	1.	160.0	164.7	16801.3	20508.0	689.0	183.9	143.8
250.	6691.	11111	2.646	36	23	57.7	1.	143.9	152.4	8802.7	52317.4	500.6	204.5	122.9
231.	6681.	11111	2.000	89	46	55.6	1.	125.6	131.1	11894.9	6034.3	460.1	185.8	119.1

Provided that enough functions of the type $U(t)$ have been computed, it becomes possible at the outlet, after some calculations, to obtain a function $\Omega(t)$ for each component from a linear K-order combination.

We can then write

$$\Omega(t) = 0 \text{ for } t \leq t_{0_1+K-1}$$

the numerical value of K being chosen so that the three conditions (16) be satisfied.

For each component, the required Maxwell's exponential solution is represented by an expression of the type

$$e^{\frac{t}{\tau}} \int_0^{\infty} e^{-\frac{t}{\tau}} \Omega(t)\, dt$$

The following in practice may substitute the expression of the preceding type

$$e^{\frac{t}{\tau}} \int_0^{t=5\tau} e^{-\frac{t}{\tau}} \Omega(t)\, dt$$

After having constructed enough sets of five solutions of this type it becomes possible to operate several statistical calculations. Threefore, we obtain the longitudinal direction defined by the angle value « Θ » (13) and, after rotation of the axis, the various apparent resistivities versus the time constant τ which are expressed under the form of the two examples given by soundings 83 and 62. No more details are to be given of the process outlined. Particularly it presents a few practical problems which concern only the specialist and that would exceedingly overload the present text.

Presentation of results

The process described above requires a large memory capacity computer in order to handle five-component recordings. For instance, the data above were processed on a CDC - 7600 computer.

The best way to discuss the type of results obtained is to examine a print-out from the computer after processing with a programme using the exponential solutions.

The two examples mentioned above are from recordings made respectively at two stations in the area of Travale (Italy). The duration of each recording was 1 h 30 m and the sampling rate was 2 scans/sec. The results are shown on a fourteen column chart which will be described summarily. $T = 5400$ sec, $f = 0.0001$

The fourth column « RATO » shows the values of the square root of τ arranged in decreasing order from the first row, and in function of which are explicited all the other computed values.

The column « THETA » indicates the values of the angle Θ between the longitudinal direction and the OX axis in the coordinate system described above.

The column « SIGTH » shows the sign of THETA, with respect to the OX axis: « 1 » indicates a positive value; « —1 » indicates a negative value; « 0 » indicates indetermination of sign. The values of Θ and their sign are computed independently of one another. The column « NTH » indicates a possible weighting concerning the computed sign.

The columns « ROALON, ROATRA, ROALORES, ROATRARE, ROAVERT » give respectively apparent longitudinal resistivities, apparent transversal resistivities, apparent residual longitudinal resistivities, apparent residual transversal resistivities, and apparent vertical resistivities, which are defined on page 5.4.5

The columns ROX, ROY, indicate the apparent resistivities which would have been obtained along the OX and OY axes respectively, had only one telluric component and one magnetic component been used for each of these axes. The first three columns indicate recording and process characteristics.

The values of θ obtained are generally very good. In any survey, a map of the longitudinal directions may be obtained from them. In areas with geothermal anomalies, the computed longitudinal directions vary very little as a function of τ for any given station.

There is little dispersion of the values of ROALON. The numerical value of the longitudinal conductance may be computed from ROALON for the station considered.

Thus, it is possible to map the longitudinal conductance prevailing in the surveyed region.

Numerical values listed in the ROATRA column may sometimes show a wider dispersion in the case of perfect cylinder geometry. This is due to the fact that, when having to deal with a perfectly cylindrical structure, telluric currents tend to flow along the main trends, for obvious reasons of symmetry.

Nevertheless, the numerical value of the transversal conductance for each station may be computed from ROATRA as well.

The numerical difference between the longitudinal conductance and the transversal conductance may be very large and particularly significant in geothermal exploration.

It should be noted that the apparent resistivities ROX and ROY may show large differences for any station.

The values of ROATRARE and of ROALORES may show some dispersion. They are used only to indicate, by their order of magnitude, whether or not there is a case of cylindrical symmetry. Sometimes, the values of ROAVERT are also somewhat dispersed.

Only their order of magnitude is used. Small numerical values of ROAVERT indicate the proximity of a geological anomaly of some amplitude.

Conclusions

The M.T.-5-E.X. method applied to geothermal exploration defines quantitatively the directional characteristics of electromagnetic phenomena, and thus detects and locates abrupt anomalies in the subsurface. In a paper to be published in *Geothermics*, results will be shown of an M.T.-5-E.X. survey with 84 recording stations, over about 30 km^2 in the region of Travale (Italy).

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UNIVERSITY OF UTAH RESEARCH INSTITUTE

UURI

EARTH SCIENCE LABORATORY
391 CHIPETA WAY, SUITE C
SALT LAKE CITY, UTAH 84108—1295
TELEPHONE 801-524-3422

6 Octubre, 1984

D. Fernando Huertas
LAW ENGINEERING IBERICA, S.A.
Corazón de María, 2
28002 - Madrid

Muy señor mio:

Teniendo el conocimiento del "Proyecto para analisis y valoracion de las tecnicas geofisicas aplicadas a la investigacion geotermica", anunciado en el Boletín Oficial del Estado de fecha 19 de Septiembre de 1984, y conociendo las condiciones técnicas y administrativas del mismo, nos complace comunicarle nuestra aceptación de colaboración con ustedes tanto con los medios humanos como materiales necesarios para la realización del proyecto.

Sin otro particular y esperando sus noticias le envía un cordial saludo,

P. M. Wright
Director Adjunto

PMW/jp

PROPOSAL MATERIALS

FOR AN

EVALUATION OF GEOPHYSICAL METHODS

IN GEOTHERMAL EXPLORATION

by

The Earth Science Laboratory
University of Utah Research Institute
391 Chipeta Way, Suite C
Salt Lake City, Utah 84108
USA

CONTENTS

PROPOSED APPROACH

The Earth Science Laboratory/UURI has acquired considerable experience in applying geophysical methods to geothermal exploration and resource assessment during the last seven years. In addition to numerous studies in the western United States we have completed geophysical field surveys or data interpretations and reviews for geothermal areas in El Salvador, Ecuador, Kenya, Ethiopia, Ascension Island, Hawaii, and in Alaska. Geophysicists at the Earth Science Laboratory are also well known for their contributions to the technical geophysical literature and their experience in mining geophysical methods.

We propose to conduct an extensive search of the worldwide technical literature to become more familiar with those applications of geophysical methods to geothermal exploration which we have not already encountered. The results of this literature search will be documented in a bibliography. Information determined from the literature search, supplemented by studies in ESL/UURI files and our personal experience will be critically reviewed. An evaluation of the cost-effectiveness, resolution capabilities, and limitations of the various geophysical methods will be completed and documented in a technical report. An exploration strategy will then be developed for the use of geophysical methods in sedimentary basins, volcanic areas and granitic areas.

STATEMENT OF WORK

1. The ESL/UURI will complete a literature search of the worldwide published data base for technical reports pertaining to geophysical applications in geothermal exploration. We will initiate the search by accessing the major computer data base files which are currently available. The main geophysical and geothermal technical publications and indices, many of which are a part of the ESL/UURI technical library, will also be searched.
2. A comprehensive bibliography will be compiled which will document the relevant technical papers and reports resulting from the literature search described above.
3. A statistical tabulation will be completed which presents the relative frequency of use of various methods, available information on costs, and applicability for various geologic regions.
4. An evaluation of the spatial resolution, ambiguity, limitations, and general effectiveness of the various geophysical methods will be completed and supported by technical discussions or references to the published literature.
5. A detailed analysis will be completed of the effects of temperature, pressure and fluid content on rock resistivity. The analysis will be supported by references to the technical literature and calculations as may be appropriate.
6. An exploration strategy will be developed (see attached example) for three different geothermal resource geologic occurrence models: sedimentary basins, volcanic areas, and granitic areas. The exploration strategy will include a discussion and critique of method applicabililty and effectiveness in the different geologic environments.

7. A final report will be written in Spanish which documents the method evaluations, tabulations, technical considerations and exploration strategies for prospective geothermal areas in Spain.

DELIVERABLES

The following deliverable items will result from the study and be submitted upon completion of the project.

1. A detailed bibliography documenting the results of the literature search.
2. A final report documenting method evaluations and applications and exploration strategies for geothermal areas in Spain (in Spanish).
3. UURI will submit one copy each of approximately 15 technical reports documenting geophysical work in geothermal areas in the United States in which UURI has been directly involved. These detailed studies are not available in the published literature.
4. UURI will submit on computer tape copies of three geophysical data interpretation programs. The programs are written in Fortran IV specifically for a PRIME computer system and will require some conversion to be used on computers in Spain. The cost of this conversion is not included in this proposal. We propose to supply the following computer programs:

GM3D	Three-dimensional gravity and magnetic prism modeling program
GRAV2D	Two- and 1/2-dimensional gravity modeling program
IP2D	Two-dimensional IP and resistivity modeling program

BUDGET

The Earth Science Laboratory/UURI proposes to complete this project for the fixed price cost of 2,312,000 pesetas. The principal cost items are identified below:

<u>Salaries, Wages and Benefits</u>		$13,280
Phillip M. Wright and/or Howard P. Ross	20 man-days	
Advanced geophysical student	32 man-days	
Secretary	5 days	
<u>Computer Bibliographical Search</u>		220
<u>Publications and Reproductions</u>		60
	Total	$13,560
	Total	2,312,000 pesetas

Copy w/o letterhead

LETTER OF TRANSMITTAL

December 19, 1984

The following items are submitted in partial fulfillment of the deliverables required for the Geophysical Portion - Geothermal Study, Instituto Geologico Y Minero De España.

1. Outline of final report
2. Outline of bibliographical report
3. Expanded project status report
4. ESL/UURI and UUGG geothermal exploration reports (18) (see attached list)
5. ESL/UURI geophysical computer program user guides and program documentation (3) (see attached list)

SPAIN IGME - REPORT FORMAT

I. EXECUTIVE SUMMARY

II. INTRODUCTION

III. GEOLOGIC OCCURRENCE OF GEOTHERMAL RESOURCES
- A. Resource Types
  1. Convective hydrothermal
  2. Geothermal gradient
  3. Deep sedimentary basin
  4. Geopressured
  5. Radiogenic
  6. Hot dry rock
  7. Magma
- B. Worldwide distribution of resource type (Tabulation and Map presentation)

IV. GEOTHERMAL RESOURCES OF SPAIN
- A. Sedimentary Basins
- B. Igneous Areas
- C. Volcanic Areas

V. PHYSICAL PROPERTIES ASSOCIATED WITH GEOTHERMAL SYSTEMS
1. Density
2. Magnetic Susceptibility
3. Electrical Resistivity
4. Temperature
5. Fluid Flow
6. Seismic velocity
7. Seismicity

VI. GEOPHYSICAL METHODS APPLIED TO GEOTHERMAL EXPLORATION (Description, applicability, critique)
1. Introduction
2. Thermal Methods
3. Electrical Methods
   - a. Introduction
   - b. Magnetotelluric (and CSAMT)
   - c. Electrical resistivity
   - d. Electromagnetic soundings
   - e. Induced polarization
   - f. Self-potential
4. Seismic Methods
   - a. Introduction
   - b. Passive seismic
     - i) Seismic emissions
     - ii) Microearthquake
5. Magnetic methods
6. Gravity methods
7. Well logging

SPAIN - IGME GEOPHYSICS IN GEOTHERMAL
Bibliographical Search

Project Status Report

GEOPHYSICS IN GEOTHERMAL EXPLORATION

1. The bibliographic search of the GEOREF computer base has been completed. More than 1200 listings for geophysical investigations in geothermal energy were noted. A printout of the more appropriate 550 entries is being reviewed for a statistical evaluation and critique of the methods used. More than 100 additional papers have been listed from non-GEOREF sources.
2. A review of the four reports of geophysical studies in Spain has been completed and a critique has been drafted. This evaluation will comprise one chapter of the final report.
3. Chapters describing the geologic occurrence types of geothermal resources are being prepared.
4. The project should be completed prior to January 25, 1985.

Howard P. Ross

Howard P. Ross
Section Head, Geophysics

LIST OF REPORTS AND REPRINTS TRANSMITTED

1. Resistivity, Induced Polarization, and Self-Potential Methods in Geothermal Exploration, by S. H. Ward and W. R. Sill (ESL-108).

2. Detection of Conductive Bodies in a Layered Earth Using the Magneotelluric Method: Application to Silicic Magma Bodies, by G. A. Newman, P. E. Wannamaker, and G. W. Hohmann (ESL-113).

3. Controlled Source Electromagnetic Methods in Geothermal Exploration, by S. H. Ward (ESL-114).

4. Results of a Detailed Gravity Survey in the Alamosa Area, Alamosa County, Colorado, by C. E. Mackelprang (ESL-126).

5. A Thermal Resistance Method for Computing Surface Heat and Subsurface Temperatures with Application to the Uinta Basin of Northeastern Utah, by D. S. Chapman and T. Keho (DOE/ID/12079-79).

6. Controlled-Source Audiomagnetotellurics in Geothermal Exploration, by S. K. Sandberg and G. W. Hohmann (DOE/ID/12079-5).

7. Interpretation of a Dipole-Dipole Electrical Resistivity Survey, Colado Geothermal Area, Pershing County, Nevada, by C. E. Mackelprang (ESL-41).

8. Thermal Studies at Roosevelt Hot Springs, Utah (and two accompanying heat flow studies), by W. R. Wilson and D. S. Chapman (DOE/ID/12079-19).

9. Geophysical Investigations of the Baltazor Hot Springs Known Geothermal Resource Area and the Painted Hills Thermal Area, Humboldt County, Nevada, by R. K. Edquist (ESL-54).

10. Two-Dimensional Modeling Results of Telluric-Magnetotelluric Data from the Tuscarora Area, Elko County, Nevada, by C. E. Mackelprang (ESL-63).

11. The Cove Fort-Sulphurdale KGRA - A Geologic and Geophysical Case Study, by H. P. Ross, J. N. Moore, and O. D. Christensen (ESL-90).

12. The Effects of Regional Groundwater Flow on the Thermal Regime of a Basin, by L. Smith and D. S. Chapman (DOE/ID/12079-65).

13. Self-Potential Effects Due to Hydrothermal Convection-Velocity Crosscoupling, by W. R. Sill (DOE/ID/12079-68).

14. Documentation and Analysis of the Schlumberger Interactive 1-D Inversion Program SLUMB, by S. Samberg (ET/27002-2).

15. Bipole-Dipole Interpretation with Three-Dimensional Models (Including a Field Study of Las Alturas, New Mexico) by G. W. Hohmann and G. R. Jiracek (ESL-20).

16. Geophysical Study of the Monroe-Red Hill Geothermal System, by C. W. Mase, D. S. Chapman, and S. H. Ward (IDO/76-1601-77-17).

17. Roosevelt Hot Springs Geothermal System, Utah - Case Study, by H. P. Ross, D. L. Nielson, and J. N. Moore (Bull. AAPG reprint).

18. Exploration Strategy for High-Temperature Hydrothermal Systems in Basin and Range Province, by S. H. Ward, H. P. Ross, D. L. Nielson (Bull. AAPG reprint).

COMPUTER PROGRAM DOCUMENTATION

1. Interactive Dipole-Dipole Resistivity and IP Modeling of Arbitrary Two-Dimensional Structures (IP2D Users Guide and Documentation), by T. J. Killpack and G. W. Hohmann (ESL-15).

2. GRAV2D: An Interactive 2-1/2 Dimensional Gravity Modeling Program (User's Guide and Documentation for Rev. 1), by C. Nutter (ESL-42).

3. GM3D: Interactive Three-Dimensional Gravity and Magnetic Modeling Program (GM3D Rev. 1 User's Guide), by J. Maurer and J. Atwood (ESL-44).

Note: Magnetic tape computer code for these programs will be transmitted in a later shipment.

SPAIN GEOPHYSICS

Literature for Search

Journals and Publications

Geophysics
JGR-B (red) - Solid Earth
Geophysical Prospecting
GRC Trans.
USGS P.P.
UN Symposium
USGS O.F.
Geothermics
TRANS - AGU (Abstracts)
AAPG Bull.

Reports

ESL/UURI
LBL
LANL
USGS O.F.
Hawaii Inst. Geophys.
Colo. Sch. Mines Bull.
Japan Geol. Survey
OIT reports
PR China Geol. Survey
VPI
DOGAMI (Ore State)

HPR

USAGE OF GEOPHYSICAL METHODS IN GEOTHERMAL

by area/country and geologic occurrence type

Thermal Methods
1. Shallow Temp (0-6 m)
2. Thermal Gradient
3. Heat Flow
4. Infra-red

Electrical
Magnetotelluric (MT)
Audio MT (AMT)
CSAMT
Electromagnetic (shallow, mid-hi freq)
TDEM
Other EM
MT.-S.-E.X.

Electrical Resistivity
a) bipole-dipole (total field)
b) dipole-dipole
c) Schlumberger VES or profiles
d) pole-dipole
e) other arrays
f) induced polarization
g) self-potential

Magnetics
a) aeromagnetic
b) ground magnetics

Gravity
Regional and general
Very detailed reservoir scale (0-10 km)

Seismic Methods
Active: Refraction
Reflection, deep (d > 1000 m)
Reflection, shallow (0 < d < 1000 m)

Passive: Regional earthquake data base
Microearthquake surveys
Seismic noise
Seismic emissions

Well Logging

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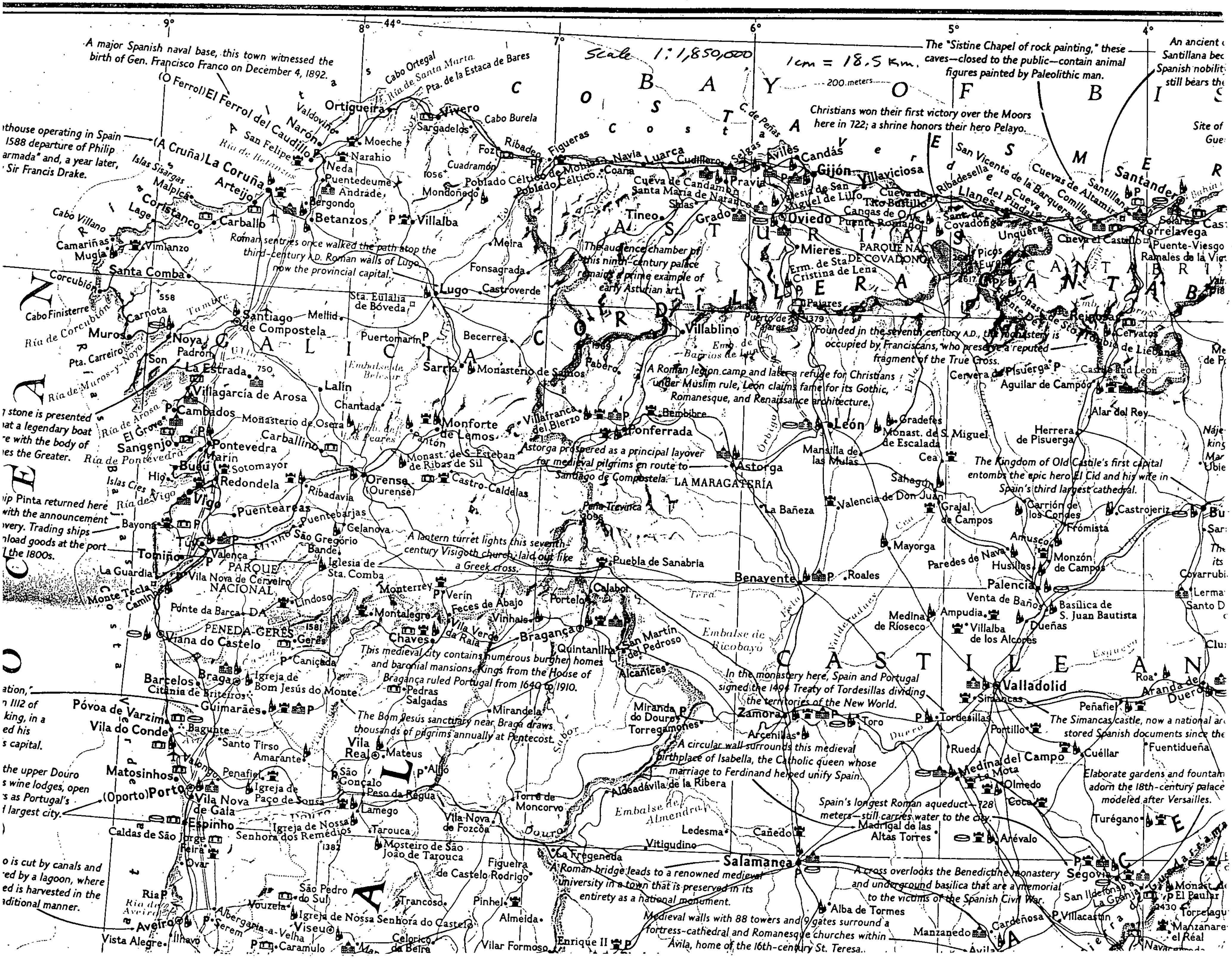
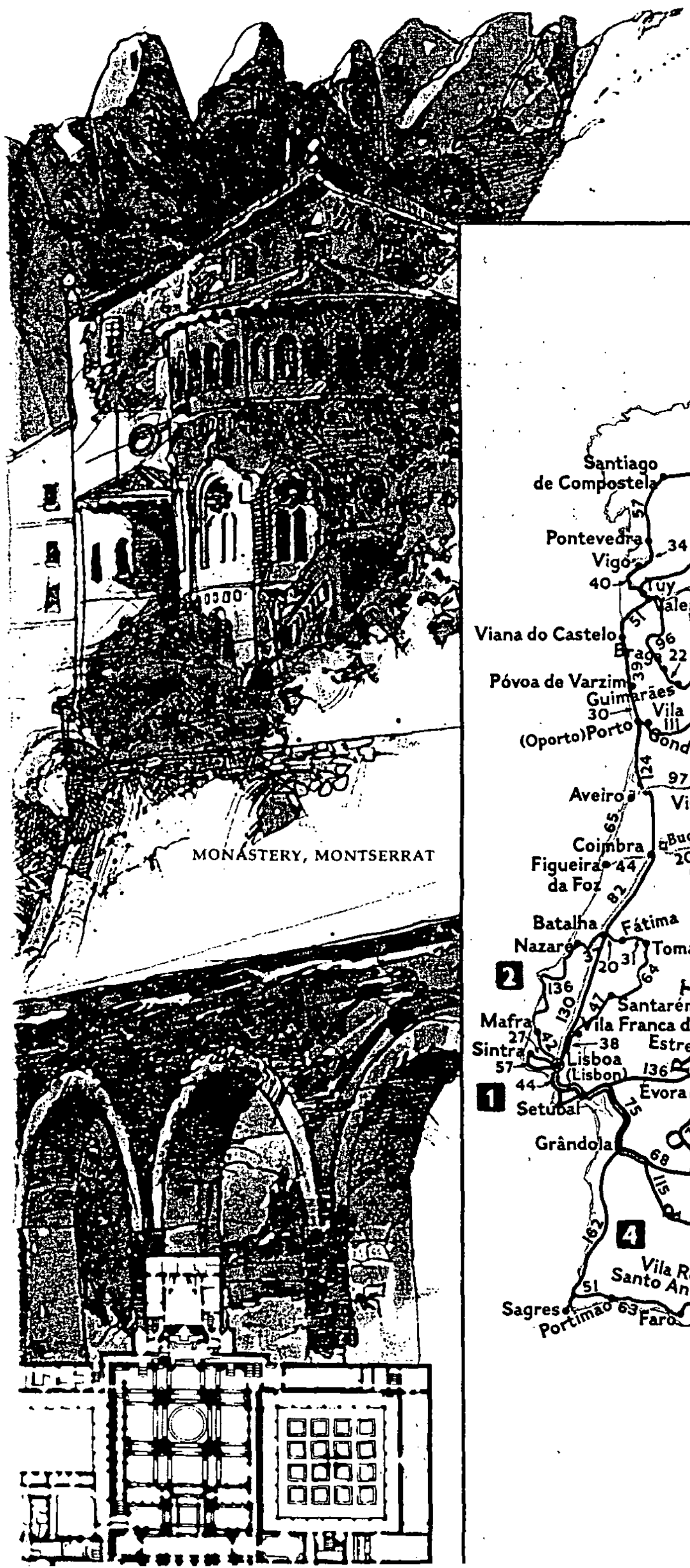
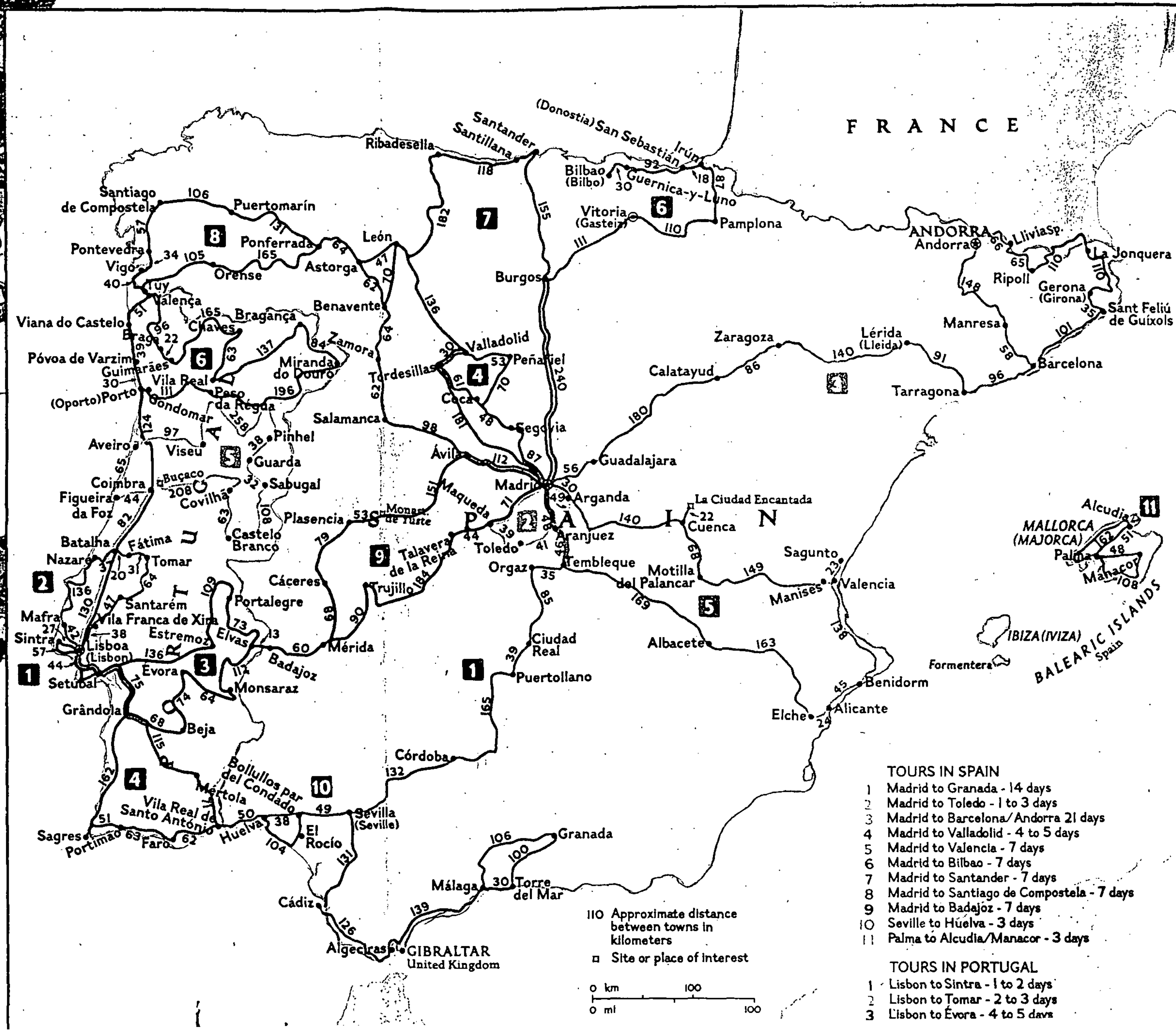


Scale 1:1,850,000 1cm = 18.5 Km.
A major Spanish naval base, this town witnessed the birth of Gen. Francisco Franco on December 4, 1892.
(O Ferrol) El Ferrol del Caudillo
The "Sistine Chapel of rock painting," these caves—closed to the public—contain animal figures painted by Paleolithic man.
Christians won their first victory over the Moors here in 722; a shrine honors their hero Pelayo.
B A Y O F B I S
C O S T A V E R D E
C O S T A
(A Cruña) La Coruña
Roman sentries once walked the path atop the third-century A.D. Roman walls of Lugo, now the provincial capital.
The audience chamber of this ninth-century palace remains a prime example of early Asturian art.
A S T U R I A S
C O R D I L L E R A C A N T Á B R
G A L I C I A
Founded in the seventh century A.D., the monastery is occupied by Franciscans, who preserve a reputed fragment of the True Cross.
A Roman legion camp and later a refuge for Christians under Muslim rule, León claims fame for its Gothic, Romanesque, and Renaissance architecture.
Astorga prospered as a principal layover for medieval pilgrims en route to Santiago de Compostela.
LA MARAGATERÍA
The Kingdom of Old Castile's first capital entombs the epic hero El Cid and his wife in Spain's third largest cathedral.
A lantern turret lights this seventh-century Visigoth church, laid out like a Greek cross.
PARQUE NACIONAL PENEDA-GERÊS
PARQUE NAC. DE COVADONGA
This medieval city contains numerous burgher homes and baronial mansions. Kings from the House of Bragança ruled Portugal from 1640 to 1910.
In the monastery here, Spain and Portugal signed the 1494 Treaty of Tordesillas dividing the territories of the New World.
C A S T I L E A N
The Simancas castle, now a national archive, stored Spanish documents since the
The Bom Jesús sanctuary near Braga draws thousands of pilgrims annually at Pentecost.
A circular wall surrounds this medieval birthplace of Isabella, the Catholic queen whose marriage to Ferdinand helped unify Spain.
Elaborate gardens and fountains adorn the 18th-century palace modeled after Versailles.
Spain's longest Roman aqueduct—728 meters—still carries water to the city.
A Roman bridge leads to a renowned medieval university in a town that is preserved in its entirety as a national monument.
A cross overlooks the Benedictine monastery and underground basilica that are a memorial to the victims of the Spanish Civil War.
Medieval walls with 88 towers and 9 gates surround a fortress-cathedral and Romanesque churches within Ávila, home of the 16th-century St. Teresa.
(Oporto) Porto
Santiago de Compostela
Lugo
Oviedo
Gijón
Santander
León
Astorga
Ponferrada
Orense (Ourense)
Vigo
Pontevedra
Braga
Bragança
Chaves
Zamora
Salamanca
Valladolid
Palencia
Segovia
Tordesillas
Medina del Campo
Benavente
Vila Real
Viseu
Aveiro
Lamego
Guimarães
Tui
Valença
Villablino
Monforte de Lemos
Sarria
Betanzos
Villalba
Ribadeo
Luarca
Avilés
Llanes
Torrelavega
Reinosa
Aguilar de Campóo
Sahagún
Toro
Coca
Arévalo
Cuéllar



MONASTERY, MONTSERRAT



Geothermal Resources Council, TRANSACTIONS, Vol. 1 May 1977

GEOTHERMAL:

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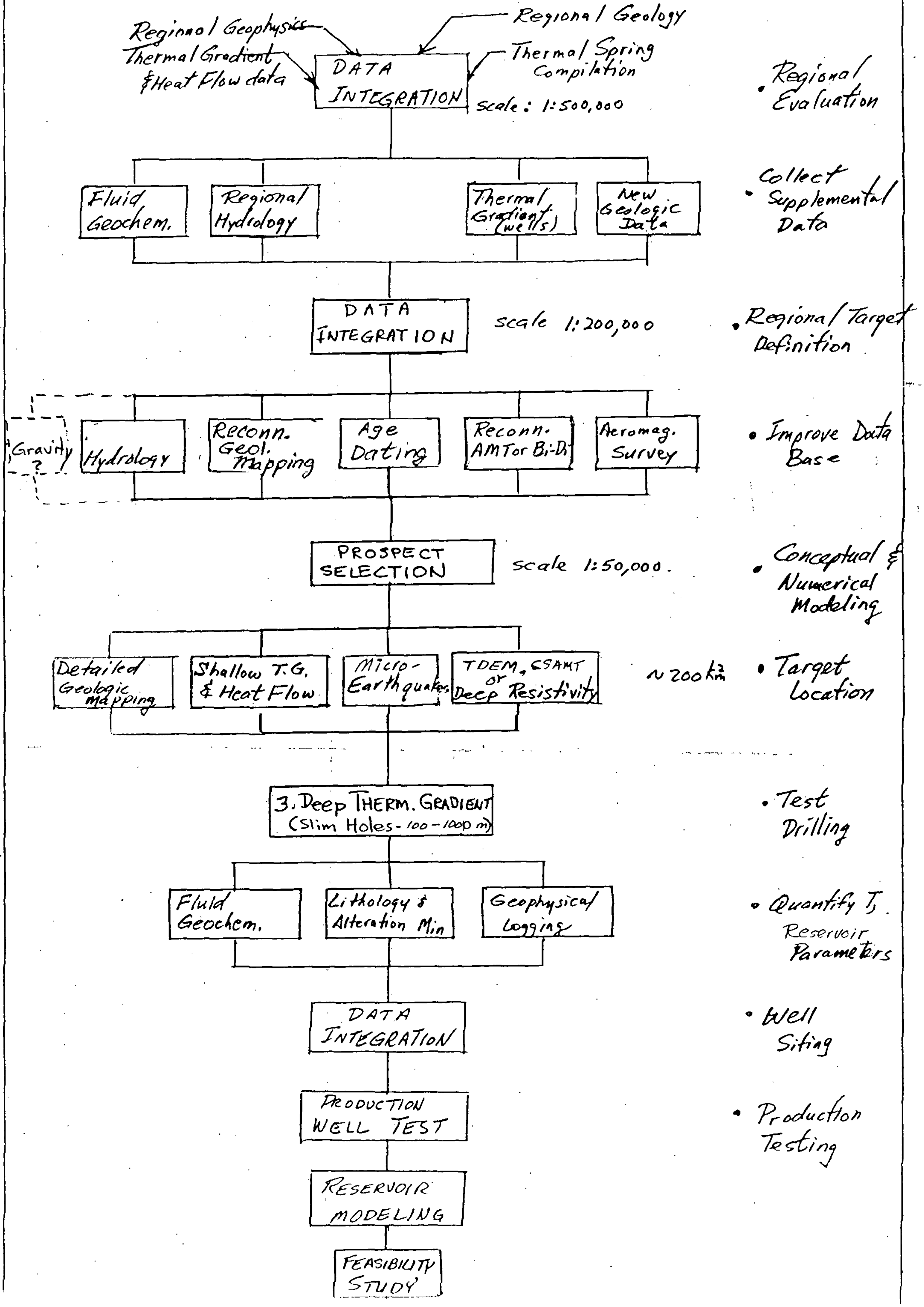

GEOTHERMAL ENERGY: A NOVELTY BECOMES RESOURCE

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GEOTHERMAL ENERGY:
BET ON IT!

TRANSACTIONS, VOLUME 8

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GEOTHERMAL ENERGY IN THE USSR

A Survey of Resources, Methodology, Geology, and Use

(144 pgs.)

Savely Polevoy

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Research Institute
Salt Lake City, Utah 84108

23 July 1985

Dear Sirs:

At the request of the author, Savely Polevoy, we are sending you a copy of our recent publication on Soviet geothermal energy. We would welcome any comments you might have.

After you've had a chance to examine the study, kindly forward it to your institution's library so that it might be made available to other readers.

Sincerely,

Steven Jones
Program Manager

SJ:pih

CONTENTS

FOREWORD

This monograph details research and development of geothermal energy resources in the USSR, describes geologic occurrence and technical state-of-the-art production methodology, and offers a prognosis for future growth in the Soviet geothermal industry. The author combines his geohydrological career experience with an extensive literature review to offer a comprehensive report that should interest geotechnical readers and also those who study the workings of the Soviet science and technology bureaucracy. Chapters 1 and 4 deal with where the geothermal industry has come from, the problems it faces, and where it is going. Chapters 2 and 3 detail the how and where of geothermal production, and include estimates of reserves.

State-wide support for geothermal research and development began in 1964 in the USSR. Prior to that time, more than 50 geothermal basins and volcanic sources had been identified, electric power generation potential had been suggested, and the first geothermal map of USSR had been prepared. A comparable nationwide effort of roughly the same magnitude was started at about the same time in the US.

In the late 1960s, low- and medium-potential geothermal waters, with temperatures less than 100°C, gained widest use. By 1972, 62 wells were in production and the Pauzhetka geothermal power plant was producing 15 million kW annually. This experimental plant was built to prove the feasibility of using steam-water mixture to generate electrical energy and its economic viability. Both were demonstrated. The hierarchy that was responsible for R&D support and growth during this early period, and still serves today, is described in chapter 1.

In 1979, thermal water energy provided heat for 4,500 apartments, hot water for 300,000 people, heated 50 hectares of hothouses, and generated 16 million kWh of electricity. In 1980, the Soviet Union was exploiting 36 geothermal water fields (GWFs) comprising 170 wells that produced 40 million m^3 of hot water. Steam production, which occurred only at the Pauzhetka power station, was 250-300 thousand tons annually in the period 1968-1980. Although they fell short of plan targets, these figures represent but a fraction of hypothetical Soviet thermal and superheated water reserves. Estimates of hypothetical thermal water reserves show the overall energy of these reserves to be on the order of 200 million Gcal annually.

All Soviet geothermal water fields (GWFs) are of the hydrothermal type where the liquid phase dominates. There is no production from hot dry rock (HDR) or magma sources because technology is insufficient. But then again, there exists no place in the world a technology for the production of energy from HDR. Two basic types of GWFs are exploited: stratal water-pressure systems, and fissure-vein systems. The stratal GWFs produce mainly from sedimentary formations that are widespread on platforms, in foredeeps, and in intermontane depressions where Mesozoic and Cenozoic deposits contain extensive volumes of thermal water, generally at 75-100°C. Fissure-vein fields produce from fracture systems that relate to on-going tectonic activity and volcanism where water temperatures may reach 300°C. Drilling technology in each field type is different. In stratal systems, wells are generally about 2,000 m in depth, and have bottom diameters averaging 152 mm. This depth is greater than the average depth of comparable US wells. In fissure-vein systems, wells are in the 400-600 m depth range, and special precautions are taken during their construction. Geophysical techniques used in fissure-vein exploration include DC electro-profiling (bilateral dipolar), and correlative refractive wave profiling methods. In the US, essentially similar methods and techniques are in use.

Stratal systems and formations are evaluated by hydrodynamic calculations and simulations based on wellhead data. These calculations were the result of original research by the author, which yielded a unique method to determine small pressure differences in wells with a high degree of accuracy. Flow tests on wells in the USSR are varied but are similar to U.S. techniques; these may last several days or months, and ideally lead to a 25-year forecast of well or field performance. Forms of the Theis equation and elastic regime filtration theory are applied to estimate performance of stratal wells; boundary problems and anisotropy enter into calculations aimed at the 25-year forecast. These analytical methods vary little from those used at cold water wells. Simulations of well field performance include network electric (RC networks) and series analog methods.

Fissure-vein systems, however, are evaluated empirically. These yield steam-water mixtures, are generally non-Darcian inflow behavior, and their explorable reserves exceed natural discharge by a factor of 3 to more than 30. Well tests in fissure-veins systems usually last at least a year to allow impact of the seasonal hydrologic cycle to be seen.

Formulas for determining static and dynamic pressures from wellhead data, heat conductivity within the open borehole, and impact of drawdown are presented. All of the evaluation methods presume a gushing well production mode. Exploitation by pumping is currently economically unfeasible in the USSR, but studies are continuing with the aim of developing an economical pump for geothermal wells. Chronic problems in geothermal wells include control of sand bridging, corrosion, and salt encrustation. Similar problems are encountered in other parts of the world (Hungary, Iceland, New Zealand, and elsewhere), where similar hydrogeothermic features are found.

Geothermal resources are widely spread across the Soviet Union in eleven geologic provinces. Structural, tectonic, and stratigraphic settings, well yields, and mineralization levels in each province are reviewed, and reserves are predicted.

In addition to the single operating power plant at Pauzhetka, other projects are underway in the Stavropol, Dagestan, and Transcaucasian areas. Current technology permits recovery of more than 20 kWh of electric energy per ton of water at 150°C.

Even so, geothermal electric plants are on the periphery of expected Soviet energy production. Because more than 90% of geothermal reserves are between 40-100°C, the most practical uses are for hot water supply for space heating, e.g., residential complexes and greenhouses, and for health spas--long a popular use in the Soviet Union.

Breakthroughs in hot dry rock (HDR) technology appear necessary if there is to be significant increase in geothermal production. The development of high temperature underground boilers in the USSR will be realized only if a number of hydrological, seismic, and economic problems that relate to the drilling and casing of superdeep boreholes in high temperature conditions (300-500°C) can be solved. The USSR has developed an installation for drilling superdeep boreholes to 15 km: the Uralmash 15000. However, the extremely small bottomhole diameter it produces is inadequate for creating underground boilers at great depths.

Nonetheless, the 1990s are expected to see production of conductive HDR heat in volcanic regions of Kamchatka and permafrost areas of the northeastern USSR via underground thermal boilers lying at depths of up to 3 km. By the turn of the century, high-temperature (400-600°C) thermal boilers in HDR at depths of 6-15 km should come into use.

In the USSR no separate administrative structure for geothermal energy has been developed. Exploratory efforts for thermal water are still carried out by two ministries: the Ministry of Geology and the Ministry of the Gas Industry, while extraction and sale of thermal water is conducted solely by the latter. The lack of an independent organization hinders geothermal development and results in irregularities in planning, distribution of resources, and allocation of materials and equipment.

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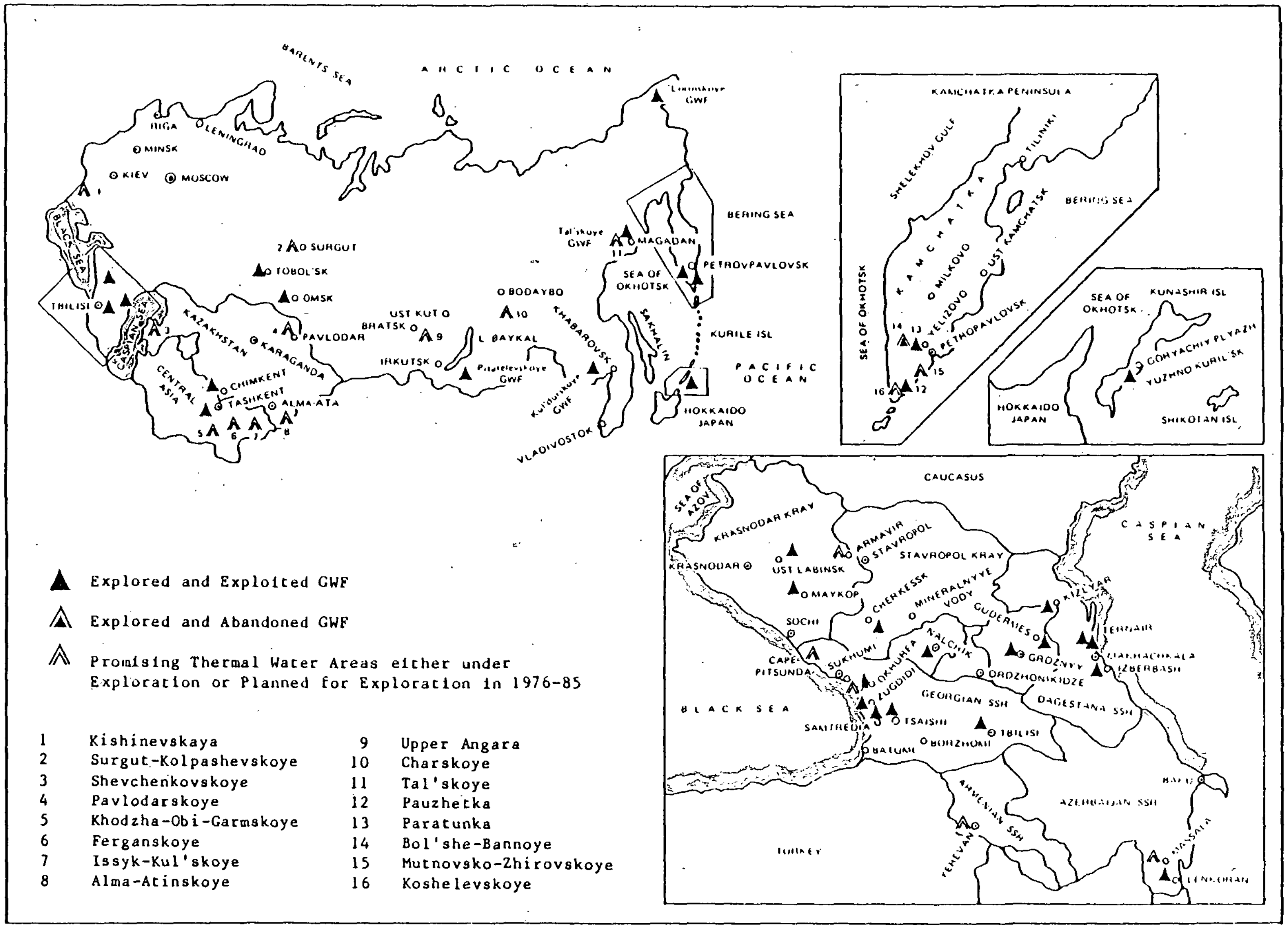
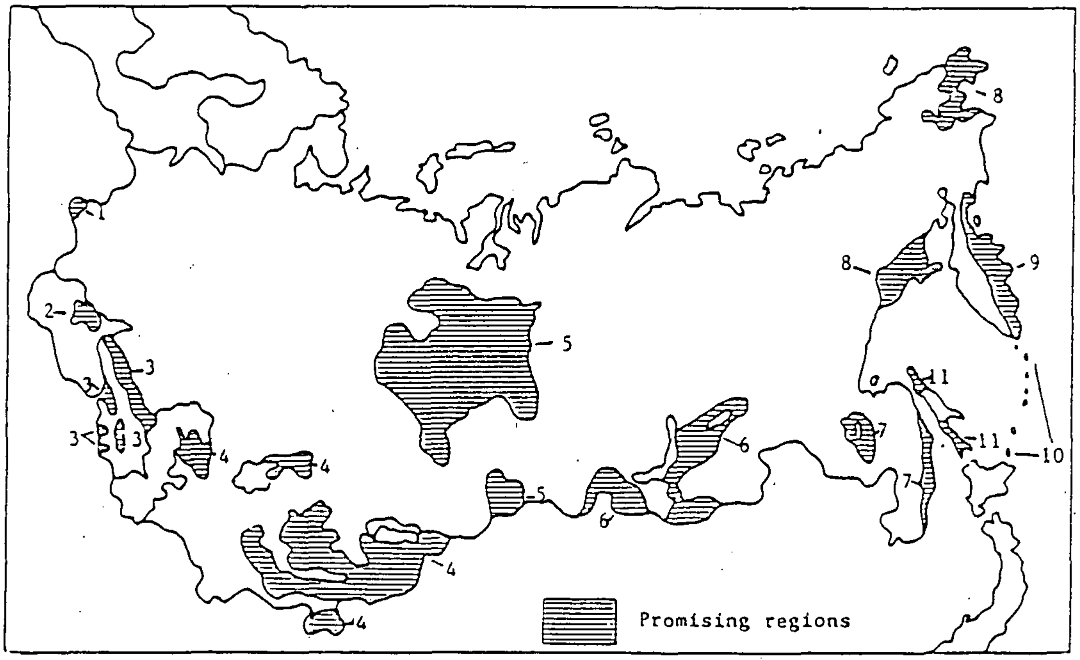


FIGURE 10

DISTRIBUTION OF GEOTHERMAL WATER FIELDS AND EXPLORATION AREAS IN THE USSR

FIGURE 11

DISTRIBUTION OF PROMISING THERMAL WATER AREAS IN THE USSR



Note: Numbers correspond to chapter III subsections.

Source: Mavritskiy, B. F., et al. Resursy termal'nykh vod SSSR. Moscow, Nedra, 1975.

Fissure-vein thermal water is usually limited to metamorphic, volcanic-sedimentary, and igneous rocks of varying ages that form the fold regions and basements of artesian basins. This water is generally found in tectonic fault areas in small artesian systems. Vertical circulation dominates the dynamics of fissure and fissure-vein water, in contrast to the lateral circulation dominant in stratal systems. Fissure discharge is in the form of springs and sometimes steam jets, as well as hidden discharge on the basement surface beneath the artesian basins. In the USSR there are up to 150 groups of springs and individual flows with temperatures above 40°C, which are concentrated primarily in mountainous regions in the southern and eastern parts of the country and in the Transbaykal region. Thermal springs are also known in the northeast areas (Kolyma, Chukotka), where they penetrate to the surface through thick layers of permafrost (Salygan-Sylba, Lorinskiy, and Talskiy springs). The Kurile-Kamchatka volcanic zone is a unique site. Here, numerous hot springs and steam jets are tied to magmatic activity. The greatest spring flow volumes recorded in the USSR have been observed in this region and in the Sayan-Baykal fold area.

Geologic Settings of Geothermal Waters

Thermal waters in the USSR are distributed in 11 geologic provinces (from west to east): (1) Carpathia; (2) Crimea; (3) Caucasus; (4) Central Asia and Kazakhstan; (5) Western Siberia; (6) Southern part of East Siberia; (7) Transbaykal and the Amur Region; (8) the Northeast and Chukotka; (9) Kamchatka; (10) Kurile Islands; and (11) Sakhalin (figure 11).

1. Carpathia

The Carpathian area lies in the seismically active Alpine montane fold belt that extends from the Pyrenees and Alps in Western Europe to Tien Shan and the Pamirs in Central Asia.

A promising target for thermal water is the regionally distributed Sarmatsko-Levantinian water-bearing complex (Miocene) in the Chop-Mukachevskaya intermontane basin in Carpathia. Water-bearing strata include terrigenous and pyroclastic fragmental rocks (sandstones, siltstones, tuff, and tuffites). Thermal water production from wells reaches several hundred cubic meters per day, and water temperature is about 50°C. Overall mineralization of thermal water usually does not exceed 10-15 g/l.

In the Sarmat-Levantinian water-bearing complex, hypothetical exploitable reserves of thermal water have a temperature of 50°C and a flow rate of 545 l/s, and the thermal potential is estimated to be

ABOUT THE AUTHOR

Savely Polevoy began his career as a hydrogeologist for the USSR Geological Service in 1956. He received his doctorate from the Novocherkassk Polytechnic Institute. His extensive professional experience includes participation in numerous exploratory and estimation efforts to provide a centralized agricultural and drinking water supply in Kazakhstan and the Northern Caucasus. In 1964, Dr. Polevoy began working for the Northern Caucasus Research Institute for Gas in the city of Stavropol, where he performed scientific and research work related to the use of geothermal energy. From 1971 to 1980 he took part in broad research involving prevention of ground water pollution and depletion in Northern Caucasus and Transcaucasus (Georgia).

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Since 1970, the USSR has allowed the departure of a great number of its citizens. The US public is aware of a large number of Jewish emigres--exceeding 200,000--of whom about half have settled in the United States. There has been, however, an unnoticed exodus of ethnic Germans and Armenians, as well as members of other national groups. These emigres provide an opportunity for enriching our understanding of the Soviet Union, offering us a view of conditions as they really are, not filtered by censorship or embellished to serve political purposes.

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GEOPHYSICAL METHODS IN GEOTHERMAL EXPLORATION

BIBLIOGRAPHIC SEARCH

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INTRODUCTION

A bibliographic search of geophysical and geothermal journals, published reports and transactions from technical meetings was undertaken in order to establish and document the application of various geophysical techniques used worldwide for the exploration of geothermal resources. Over 700 pertinent references were assembled and are listed at the end of this report. A data base which indicates the worldwide application of various geophysical methods for geothermal exploration was created by reviewing the more significant publications within the bibliography. This data base was then used to evaluate the effectiveness of the geophysical methods within specific geologic and tectonic settings.

PRINCIPAL LITERATURE SOURCES

A computer-aided bibliographic search was conducted using the GEOREF data base of Dialog Information Services, Palo Alto, California. This search resulted in an extensive listing of technical articles which describe the application of geophysical methods for the exploration of geothermal resources around the world. A total of 554 listings was obtained which included references from technical journals, transactions and extended abstracts from technical meetings, government publications, doctoral and masters theses and geothermal texts. Approximately 200 additional references were obtained through a specific literature search, so that the total number of bibliographic references exceeds 700.

The GEOREF bibliographic entries are included in Appendix A of this report and are listed according to a GEOREF identification number which includes the year that the reference was placed in the data base. The most recently published references are generally listed first with the article title shown in boldface lettering. Unfortunately, there is no author cross-reference to aid in the search for a particular article. A bonus with this reference list is the list of key words that accompanies each reference entry. These key words provide valuable information regarding the articles. Abstracts are also included for some of the more recent listings.

The 200 additional references came from transactions of selected technical meetings, texts and technical journals. These references are listed by the publication and then by the author and article title in Appendix B of this report. Time did not permit a complete reorganization of the reference material. Because of the awkward method of listing GEOREF entries, there is some duplication between the GEOREF and the supplemental reference listings.

Approximately half of the references could not be reviewed in detail because of time and cost considerations, but this did not pose a limitation to our evaluation because of the duplication of information published within the literature (e.g., some authors have published essentially the same article in three separate publications such as the USGS Open File Reports, the GRC Transactions of Meetings and a technical journal such as Geophysics). The principal literature sources for the articles that were reviewed are given in Table I along with the number of articles reviewed. It is apparent from this table that technical meetings provide a greater wealth of information about exploration techniques than do technical journals which tend to emphasize theoretical advancements.

Those references that were not reviewed first-hand still provided information regarding the application of geophysical methods because of the list of key words that were included with each reference of the GEOREF bibliography.

Types of Articles

The references within the bibliographic list are divided into four basic categories and listed according to the predominance in the reference list: (1) reconnaissance exploration, (2) technique development, (3) theoretical and (4) generalized case history references. Most of the articles that were reviewed described reconnaissance geophysical surveys in areas where very little was known about the subsurface geology. Usually a limited suite of geophysical methods were utilized and little drilling information was available to confirm the interpretation of the geophysical data. In many of these articles, a development in a particular technique is illustrated by the application of the technique in a geothermal area. Again, this type of article rarely presents an integrated interpretation and testing of the interpretation by the drill bit. Theoretical articles are the next most prevalent type and they generally do not provide much information regarding the utilization of geophysical methods for exploration. Unfortunately, the most important type of article, the case history, is also the rarest in the literature.

Organization of Tabulated Results

The geophysical methods commonly used for geothermal exploration can be divided into ten basic categories: passive seismic, active seismic, passive electromagnetic, active electromagnetic, electrical resistivity, radiometric, thermal gradient, remote sensing, borehole geophysics and potential (gravimetric and magnetic) methods. Borehole methods utilize most of the other geophysical methods within the confines of existing boreholes for reservoir analysis and fracture detection. Within each basic category are specific geophysical methods, such as the gravimetric and magnetic methods within the potential methods category. In all, twenty-seven geophysical methods were identified and are shown in Table II with their designated abbreviations and acronymns.

The geologic and tectonic settings of the geothermal areas that were reviewed were divided into five basic types in Table III: rift valley, basin and range, intrusive volcanic, extrusive volcanic and basin settings. The use of geophysical methods within an area is based on the consideration of the geology, surface terrain, accessibility, the expected reservoir type and the survey cost versus resource profitability. These factors are variable for each geothermal area, but they are influenced by the geologic environment of the area; consequently the geologic setting exerts great influence on the choice of geophysical method applied in an area.

Both rift valley (RV), and basin and range (B&R) settings are defined by their particular style of tectonic activity and geomorphology. Examples of rift valley settings are the Rio Grande Rift in the USA, the East African Rift and the Baikal Rift in the USSR; the Basin and Range Province, USA is the classical example of a basin and range setting. A geothermal resource not occurring within an RV or B&R setting will generally be in close proximity to Tertiary to Recent age volcanism or will occur within deep basins. An intrusive volcanic (VI) setting is one in which a near-surface intrusive body acts as the heat source for a reservoir. The recently emplaced dike in the Puhimau thermal area of the Kilauea volcano, Hawaii is an example of this type of setting. A special case of the VI setting is the hot dry rock (HDR) resource, such as the older silicic intrusion in the Jemez Mountains of New Mexico. The intrusive body not only supplies the heat but also becomes the reservoir, either as a result of natural or man-made fracturing within the body. When the intrusive magmatic body is much deeper within the crust and a more conventional geothermal reservoir exist, then the area is classified as an extrusive volcanic (VE) setting. Calderas, such as the Long Valley, and Yellowstone calderas and extensive volcanic fields related to subduction zones (El Tatio, Chile) are embraced by this category. Basin settings (B) are deep basins with generally low- to moderate-temperature geothermal resources that are a result of the deep circulation of meteoric waters within the basin. The Paris Basin of France is an example of this type of setting. The geopressured resources of Texas and Louisiana, USA, are also in this general category.

Information regarding the application of the geophysical methods in various geologic settings and temperature regimes in countries and regions around the world is listed in Table III. A total of 47 countries or regions (e.g., the Caribbean Sea region) and 88 geothermal resource areas (e.g., Cerro Prieto, Mexico) are represented within Table III. The country/region listings are organized according to the geologic setting and then are arranged alphabetically within each geologic group. Only significant geothermal areas with a substantial number of accessible references were listed separately within the table (e.g., the Coso Hot Springs resource area is listed separately from the other Basin and Range resource areas of the USA, while all of the resource areas in India were listed together).

Geothermal resources within each region are classified as low-temperature (T < 100°C), moderate-temperatue (100°C < T < 200°C) or high-temperature (T > 200°C) resources. The three rows comprising each entry for a region correspond to the low-, moderate- and high-temperature classifications (L, M, H), respectively. This classification is similar to the generally accepted temperature classification given by White and Williams (1975), but does differ from it in the choice of the boundary temperature between the moderate- and high-temperature regimes (200°C versus 150°C). The present classification scheme was used in order to provide a more even distribution of resource areas among the three temperature categories.

The symbol 'X' is used in Table III for known information (i.e., geologic setting, resource temperature, and geophysical method), the symbol '+' is used for information derived or inferred from details within an article and the symbol '?' is used for uncertain interpretations made by the authors of an article. Multiple usage of a particular geophysical technique within a region is not noted.

The site-specific information in Table III was gathered together and assembled in Table IV according to geologic setting and resource temperature so that the utilization of geophysical methods could be more easily analyzed according to those two important criteria. The number of resource areas that were surveyed by a geophysical method and the total number of available areas for each geologic/temperature category are shown along with the subtotals for each geologic setting within each of the five categories. Totals for the number of resource areas and the utilization of geophysical methods for the three resource temperatures are shown at the bottom of the table. An alternate presentation format for the utilization of geophysical methods is a percent utilization table (Table V) which provides the percentage of resource areas in which a geophysical method was applied (i.e., the number of areas where a particular method was used divided by the total number of resource areas of that type and multipled by 100). With this data format, the utilization of geophysical methods in different geologic settings and temperature regimes can be compared directly since the number of occurrences has been normalized by the total number of possible occurrences. This table can be further simplified by replacing the numeric data with symbolic data that represents four categories of percent utilization: utilization $\geq$ 50%, 25% $\leq$ utilization < 50%, utilization < 25% and 0% utilization. This summary (Table VI) of the percent utilization of geophysical methods graphically delineates those geophysical methods popularly applied in various geologic settings and resource temperatures.

DISCUSSION AND CRITIQUE

Before noting and discussing the findings of this study, a few comments regarding the data base are required. A large variation in the number of articles per country/resource area is found within the GEOREF reference list. Table VII lists the number of references per country/region and these figures indicate that a majority of the references cover only a few of the countries. This reference list consists of the GEOREF bibliography plus the 23 articles contained within the geoelectric and geothermal studies of the USSR and the eastern bloc countries (Adam, 1976). This point is better illustrated by Table VIII which lists the seven countries with the most references. Not surprisingly, the geothermal exploration in the USA was referenced 340 times out of a possible of 575 references, thus comprising the 59% of the reference list. The next most referenced country is Italy with 30 articles or 5% of the reference list. The other five countries, the USSR, Japan, Mexico, Iceland and New Zealand, all are referenced fewer than 30 times (less than 5% of the list). References for these seven countries comprise 80% of the reference list; consequently there is a definite bias in the data set towards geothermal exploration in the USA. To help de-emphasize this bias, all but three of the Basin and Range geothermal areas were lumped into one category (the Basin and Range region) in order to cut down on the number of US resource areas. Even so, there are 20 separate resource areas in the USA that are listed in Table III.

Another observation regarding this study is that not all results of geothermal exploration are published in the literature. This is especially true in the USA where much of the geothermal exploration was funded by private companies that have kept the survey findings proprietary. The usage of such techniques as bipole-dipole, microearthquake and controlled source AMT is more widespread in the USA and would be better represented if this proprietary information were available. However, we do not feel that this problem will affect the significant findings of this study. Most of the statistical findings of this study are obtained directly from Tables IV to VI and these results will now be introduced.

The column totals of Table IV Indicate that 88 resource areas were reviewed and a total of 562 entries regarding the usage of geophysical methods were made to Table III. These tabulations do not include the 7 resource areas and the corresponding 11 geophysical entries that could not be correlated with one of the five geologic settings because of deficiencies in the published literature. These are referred to as the 'unclassified category' in Table III. The ratio of the total number of entries to resource areas indicates that an average of 6 different geophysical methods were applied in each of the reviewed geothermal areas around the world. Using the totals for each resource temperature, the average number of geophysical methods applied per resource area becomes approximately 5, 5 and 8 for the low-, moderate- and high-temperature resources, respectively. The range in the number of methods applied for the three temperature regimes is 3 to 9, 3 to 11 and 5 to 16 respectively. The maximum number of methods per area (16) occurred in the high-temperature basin and range setting and the minimum (3) occurred in the low-temperature extrusive volcanic and the moderate-temperature rift valley geologic settings. It is reasonable to conclude that more exploration effort is expended in the more profitable high-temperature resource areas, as indicated by the number of methods applied in the three temperature regimes. The third column of Table IV also shows that the number of resource areas reported for a particular geologic setting is proportional to the resource temperature in all but the basin geologic setting. Of the five geologic settings, the extrusive volcanic setting contains the most documented resource areas (47) as compared to fewer than 14 areas for each of the other four settings.

Tables V and VI are used to determine the most popular geophysical methods for the different geologic settings and temperature regimes. Table VI is the easiest of the two tables to use since the percent utilization of a geophysical method is divided into 4 categories representing significant ($\geq$ 50%), moderate (25% $\leq$ utilization < 50%, low (< 25%) and non (0%) utilization of the method. Considering all resource areas and temperatures, only three methods saw significant utilization: VES (59%), gravimetric (52%) and temperature gradient (50%) methods. The popularity of the VES method is due to its use as a low cost reconnaissance method. The Schlumberger sounding is the most popular of the VES methods, but Wenner and dipole-dipole (e.g., equatorial dipole-dipole) soundings have also been used. Popularity of the gravity method is also due to its low cost and because of its usefulness in defining geologic structure. The widespread usage of the TG method is obvious, since it is the only geophysical technique that actually measures the property that is being sought. Seven other methods were moderately used around the world: heat flow (48%), magnetic (39%), MT (35%), dipole-dipole resistivity (33%), reflection seismology (33%), MEQ (32%), remote sensing (28%), and bipole-dipole (26%). The least used methods included CSAMT, IP, pole-dipole and geomagnetic soundings, all of which have values of percent usage less than 7%.

The subtotal row for each of the five geologic settings in Tables VI (and V) indicates the distribution of different geophysical methods in the different settings. These results can be summarized as follows:

rift valley: significant - VES method

moderate - MEQ, gravimetric, magnetic, MT, dipole-

dipole, bipole-dipole and heat flow and TG methods

B and R: significant and moderate - all of the methods with the exception of geomagnetic soundings, CSAMT, HEP, SP and BG (borehole geophysical) methods

IV: significant - gravimetric, magnetic, VES, and temperature gradient methods

moderate - reflection seismology, AMT, MT, dipole-dipole and heat flow methods

EV: significant - gravimetric and VES methods

moderate - MEQ, reflection seismology, magnetic MT, dipole-dipole, bipole-dipole, SP, heat flow, TG, and remote sensing methods

basins: significant - gravimetric, VES, heat flow and TG methods

moderate - reflection seismology, MT and telluric methods

Examining the columns of Table VI, the VES and TG methods are clearly the most popular geophysical methods employed in all of the geologic settings and temperature regimes. The rows of Table VI indicate that the greatest utilization of geophysical methods occurs in the moderate- to high-temperature basin and range geothermal resource areas; this result is largely due to the extensive geothermal exploration of the Basin and Range Province in the USA.

One obvious criticism of Tables V and VI is that the popularity of a method does not necessarily indicate its value as an exploration tool. Too often a technique that has been successfully employed in one environment is then tried in other geologic settings and reservoir types with much poorer results. The bipole-dipole technique is a good example of the blanket usage of a technique in areas where it is not well suited. The original success of the technique in outlining the boundaries of the Broadlands Field, New Zealand (Risk et al., 1970) led to its use in such areas as the Olkaria Field, Kenya where it found little success in mapping the geothermal resource.

The evaluation of the usefulness of the various geophysical techniques is the most difficult task of this study because of the few published comprehensive case studies of geothermal exploration programs. Ward (1983) provides an excellent evaluation of the geophysical methods in the exploration of geothermal resources in the Basin and Range Province of the western US. Ward evaluated 14 methods in 13 high temperature sites (including Long Valley, Coso Hot Springs, Roosevelt Hot Springs and Raft River) and concluded that: a) none of the various geophysical methods were uniformly consistent in performance; b) none of the methods was ranked in the "good" category and only five methods were ranked in the good to fair category (MEQ, gravimetric, electrical resistivity, SP and heat flow/TG); c) the least effective methods are seismic noise, magnetic and MT; and d) no combination of any four methods was ranked as "good to fair" in success at more than one site. It is noteworthy that two of the least effective geophysical methods (magnetic and MT) were significantly utilized in the basin and range geologic setting worldwide according to Tables V and VI. Additional observations made by Ward are: a) quiet periods between MEQ swarms limits the use of the MEQ method in some areas; b) reflection and refraction seismology are not always applicable to reservoir delineation; c) the magnetic method is most useful for mapping zones of magnetite destruction; d) Schlumberger soundings and dipole-dipole profiling surveys are the best electrical resistivity methods; e) CSAMT and CSFEM methods have not been sufficiently tested yet; f) scalar AMT and tellurics should be limited to reconnaissance surveys; g) the SP method shows great promise but does not always produce a recognizable signature over geothermal systems; and h) shallow heat flow/TG is not always a reliable indicator of a high quality geothermal resource.

A variety of techniques, including CSMAT, VES, SP, gravimetric, magnetic, CSFEM, dipole-dipole, bipole-dipole, heat flow and remote sensing methods, were employed in the Puhimau thermal area of the Kilauea Volcano, Hawaii. The SP and VLF tilt angle and resistivity results delineated an area associated with high surface temperatures and a Schlumberger sounding was used to determine a minimum depth to the top of the subsurface conductive dike (Anderson, 1984). Comparable results were obtained using the CSAMT method (Bartel, 1984).

Most of the geothermal areas around the world are characterized by subsurface resistivities that are less than 10 ohm-m; regardless of the host rock resistviity. Consequently, in many areas it is sufficient to map the surface manifestations (hydrothermal alterations) of a deeper reservoir using an electrical resistivity technique. This has been successfully done in the Broadlands Field, New Zealand (bipole-dipole), Dieng Plateau, Indonesia (bipole-dipole), Olkaria Field, Kenya (dipole-dipole) and Roosevelt Hot Springs, USA (dipole-dipole or CSAMT). The use of the airborne TEM techniques have taken advantage of the near surface conductive zones above geothermal reservoirs in order to delineate some anomalous areas in the western US for more detailed studies.

In the Olkaria area, shallow TG and dipole-dipole profiling provided the most useful information and the bipole-dipole method the least useful information (Noble and Ojiambo, 1975). On the Island of San Miguel, Portugal, a reconnaissance geophysical effort that utilized the bipole-dipole method to map anomalous areas in the rugged terrain followed by Schlumberger soundings and dipole-dipole profiling was used to locate a successful geothermal well. Later an AMT survey in the same area confirmed the results of the electrical resistivity survey, perhaps indicating a more cost effective method of exploring the rugged terrain of the island (Hoover et al., 1984). Both the electrical resistivity and AMT surveys showed little correlation with the results of an MT 5-EX survey in the same area.

The existence of low resistivities is not a guarantee of anomalous subsurface temperatures. Sanford et al. (1979) reported on a case study of the Elephant Butte prospect, south central New Mexico which involved the use of the bipole-dipole method, modified Schlumberger soundings and subsequent heat flow determinations. The electrical methods successfully mapped the basement structure and faulting and delineated several areas of anomalously low resistivity. However, the heat flow data did not indicate any anomalous subsurface temperatures in the area.

An area where the gravimetric method works very well is in the Imperial Valley of California, USA. The East Mesa and Heber geothermal areas are characterized by areas of high density that are associated with dense cap rocks that form as a result of the hydrothermal activity. Horizontal electrical profiling also delineated low resistivity zones associated with the areas of high flow (Meidav and Fergerson, 1972). Seismic noise and magnetic methods were of no value in these two areas; the cultural noise level in the area prevents the recording of any potential natural noise.

Areas where the seismic noise method is effective are areas where active thermal manifestations occur at the surface such as the Norris Geyser Basin of Yellowstone National Park, USA (Oppenheimer and Iyer, 1979). In the basin, horizontal electrical profiling delineated the outlines of the near-surface hydrothermal alteration and Schlumberger soundings mapped a resistive layer

(75-130 ohm-m) overlain by a conductive layer (2-7 ohm-m) which represents the vapor-dominated and condensate-dominated portions of the geothermal reservoir, respectively (Zohdy et al., 1973). A similar geoelectric structure was determined for the Kawah Kamojang Field, Indonesia (Hochstein, 1975).

The VES and HEP methods have been successfully used in Reykjanes Peninsula of Iceland to locate thermal areas (Georgsson, 1981 and Georgsson, 1984). The three high temperature geothermal fields on the Peninsula all occur within areas of low subsurface resistivity (6 ohm-m) as opposed to a background of 10-12 ohm-m.

The dipole-dipole, VES and SP methods were effective in exploring the Cerro Prieto Field of Mexico. The electrical resistivity methods delineated a shallow zone of low resistivity (< 2 ohm-m) associated with high heat flow and located the trace of the producing fault (Garcia, 1975). The SP method was used to map a fault through the producing area (Corwin et al., 1980) and attenuation and velocity anomalies derived from the MEQ data were useful in delineating the geothermal field. A precision dipole-dipole survey was also used to map the intrusion of fresh water into the production zone (Wilt et al., 1983) and a seismic reflection survey determined a reflection attenuation within the production zone (Blakeslee, 1984).

KEY FINDINGS

The important findings of this study can be summarized as:

(1) The tabulated statistics on the utilization of geophysical methods for geothermal exploration are biased towards the geothermal methodology of the USA because the reference list is dominated by articles dealing with geothermal exploration within the USA (59% of the references fall within this category;

(2) A total of 88 resource areas/regions were reviewed and 562 instances of the use of geophysical methods for geothermal resources were recorded in table form;

(3) An average of 6 different geophysical methods were utilized in each of the 88 resource areas;

(4) An average of 5, 5 and 8 geophysical methods were used in low-, moderate- and high-temperature resource areas, respectively;

(5) The number of reported resource areas for a particular geologic setting increases with increasing resource temperature, except in the case of basin geologic settings;

(6) Most of the reported geothermal areas worldwide occur within the extrusive volcanic category;

(7) The VES, gravimetric and TG methods are used in over half of all resource areas and the heat flow, magnetic, MT, dipole-dipole reflection seismology, MEQ, remote sensing and bipole-dipole are used in 25% to 50% of all resource areas;

(8) The least-popular documented methods are the CSAMT, IP, pole-dipole and geomagnetic soundings which were used in less than 7% of the areas;

(9) The popoularity of geophysical methods varies with geologic setting

and temperature of the resource, but the VES and TG methods are clearly favored in the majority of areas and temperatures;

(10) The performance of the various geophysical techniques are very difficult to evaluate in the various geologic settings because of a lack of comprehensive case studies in the literature;

(11) Ward (1983) ranked the MEQ, gravimetric, electrical resistivity, SP and heat flow/TG methods as the most effective (good to fair) and the seismic noise, magnetic and MT methods as the least effective geophysical methods for the exploration of the Basin and Range Province of the western USA;

(12) In general the electrical resistivity methods appear to be the most effective reconnaissance method for the delineation of shallow geothermal reservoirs with near surface hydrothermal alteration zones; however, the specific geologic model determines which physical parameter has the best correlation with the geothermal reservoir and has the highest signal-to-noise ratio.

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LIST OF TABLES

TABLE I

PRINCIPAL LITERATURE SOURCES

Transactions and Proceedings of Technical Meetings:

Transactions of Geothermal Resources Council Meetings 1977 - 1984 (38) [202]

Abstracts of the Annual International SEG Meetings 1979 - 1984 (55) [53]

Proceedings of the Second UN Symposium on the Development and Utilization of Geothermal Resources, 1975 (49) [49]

Proceedings of the UN Symposium on the Development and Utilization of Geothermal Resources, 1970 (22) [22]

Proceedings of the International Congress on Geothermal Waters, Geothermal Energy and Volcanism of the Mediterranean Area: Geothermal Energy, 1976 (9([9]

Technical Journals:

Geophysics (25) [57]

Geothermics (14) [14]

Journal of Volcanology and Geothermal Research (8) [4]

Geoexploration (1) [1]

Geophysical Prospecting (1) [1]

Journal of Geophysical Research (12)

Publications:

The Role of Heat in the Development of Energy and Mineral Resources in the Northern Basin and Range

Geoelectric and Geothermal Studies (East Central Europe and Soviet Asia)

Note: values within the parentheses are the number of articles listed within the GEOREF bibliography; the values within the square brackets are the number of articles actually reviewed.

TABLE II

GEOPHYSICAL METHODS APPLIED TO GEOTHERMAL EXPLORATION

Abbreviation	Method	Geophysical Category
SN	seismic noise	passive seismic
MEQ	microearthquake	
T	teleseism	
RFL	reflection seismology	active seismic
RFR	refraction seismology	
GRAV	gravimetric	potential field
MAG	magnetic	
AMT	audiomagnetotelluric	passive EM
MT	magnetotelluric	
TEL	telluric	
GEOM	geomagnetic sounding	
CSAMT	controlled-source AMT	active EM
TEM	transient EM (time domain)	
CSFEM	controlled source frequency domain EM	
VES	vertical electrical soundings	electrical resistivity
HEP	horizontal electrical profiling	
DD	dipole-dipole (polar)	
BD	bipole-dipole	
PD	pole-dipole	
IP	induced polarization	
SP	self-potential	self-potential
RAD	radiometric	radiometric
HF	heat flow	temperature gradient
TG	temperature gradient	
STG	shallow temperature gradient	
BG	borehole geophysics	borehole geophysics
RS	remote sensing	remote sensing

TABLE III

WORLDWIDE USE OF GEOPHYSICAL METHODS FOR GEOTHERMAL EXPLORATION

LOCATION	RV	BR	VI	VE	B	TEMP	SN	MEQ	T	RFL	RFR	GRAV	MAG	AMT	MT	TEL	GEOM	CSAMT	TEM	CSFEM	VES	HEP	DD	BD	PD	IP	SP	RAD	HF	TG	STG	BG	RS
RIFT VALLEYS																																	
EGYPT	X					+																							X	X			
ETHIOPIA	X					M						X												X									X
FRANCE																																	
RHINE GRABEN	X					+														+	X								X	X			
ISRAEL																																	
	X					+																							X				
KENYA																																	
	X					H		X				X									X		X	X							X		X
MEXICO																																	
CERRO PRIETO																																	
	X					H	X	X		X		X	X		X	X					X	X	X				X						X
REPUBLIC OF	X					+																					X						
DJIBOUTI																																	
UGANDA	X					M		X													X												
USA																																	
IMPERIAL																																	
VALLEY	X					H	X	X	X	X	X	X	X		X	X					X	X	X	X			X		X	X	X		
	X					L		X		X		X	X								X		X	X						X			
RIO GRANDE	X					M		X				X			X				X		X	X		X					X	X			
RIFT																																	
USSR																																	
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W. GERMANY																																	
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TAIWAN       : | | | | : : | | : | : | : | | | : | | : | | | | | : : : | | : : :
             : | | |X| :H: | | :X| :X|X: | | | : |X| :X| | |X| | : : : | | : : :
------------------------------------------------------------------------------------
             : | | | | : : | | : | : | : | | | : | | : | | | | | : : : | | : : :
THAILAND     : | | |+| :+: | | : | : | : | | | : | | :+|+|+| | | : : : | | : :X:
             : | | | | : : | | : | : | : | | | : | | : | | | | | : : : | | : : :
------------------------------------------------------------------------------------
USA          :?| | |+| :L: | | :X|X:X| : | | | : | |X:X|X|X| | | : : : |X| : : :
 ALASKA      : | | |X| :M: | | : |X: | : | | | : |X| :X| |X| | | :X: : |X| : : :
             : | | | | : : | | : | : | : | | | : | | : | | | | | : : : | | : : :
------------------------------------------------------------------------------------
             : | | | | : : | | : | : | : | | | : | | : | | | | | : : : | | : : :
 CASCADES    : | | |X| :M: | |X:X|X:X|X:X|X|X| : |X| : | | | | | : : :X|X| : : :
             : | | |X| :H: |X|X:X|X:X|X:X|X|X| : |X|X:X| | | | | :X: :X|X| : : :
------------------------------------------------------------------------------------
             : | | | | : : | | : | : | : | | | : | | : | | | | | : : : | | : : :
 LONG VALLEY : | | | | : : | | : | : | : | | | : | | : | | | | | : : : | | : : :
             : | |X|X| :H:X| |X: | :X|X:X| |X| : | | : | | |X| | :X: :X|X|X: :X:
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RAFT RIVER				X	X	M					X	X	X	X	X	X					X			X			X					X	X
				X		L				X																			X				
SNAKE RIVER				X	X	M		X		X	X	X	X	X	X	X			X		X			X			X		X				
PLAIN																																	
VALLES																																	
CALDERA			X	X		H	X	X				X	X		X	X				X	X		X	X						X			X
YELLOWSTONE																																	
NAT. PARK			X	X		H	X	X	X			X	X		+						X	X				X	X						X
USSR																																	
KAMCHATKA																																	
				X		X				X	X	X	X		X																	X	
YEMEN ARAB																																	
REPUBLIC																																	
				X		+															X												

BASINS

																	_																
EAST GERMANY					X	+									X		X												X				
TURKEY					X	M						X									X									X			
					X	H				X		X	X								X									X			
USA					X	+				+										X	+		+						X	X			
COLORADO					X	+		X	X			X	X		X	X					X	X								X			
PLATEAU																																	
					X	L						X	X																X	X			
MID-																																	
CONTINENT																																	
ROCKY MTNS.					X	M				X	X	X		X	X	X			X	X	X		X	X			X		X		X		
					X	+	X																						+	+			
SPAIN																																	
USSR																																	
EAST					X	+				+					X		X												X				
CARPATHIAN																																	
UKRAINE					X	+																							X				

UNCLASSIFIED

BRAZIL						+																							X	X			
DENMARK						+																							X				
IRAQ						+																									X		
ROMANIA						+															+												
SWITZERLAND						+																							X				
W. GERMANY URACH KGRA						+				X	X				X		X																
YUGOSLAVIA						+																							X				
LOCATION	R V	B R	V I	V E	B	T E M P	S N	M E Q	T	R F L	R F R	G R A V	M A G	A M T	M T	T E L	G E O M	C A M T	T E M	F E	V E S	H E P	D D	B D	P D	I P	S P	R A D	H F	T G	S G G	B G	R S

TABLE IV

UTILIZATION OF GEOPHYSICAL METHODS BY GEOLOGIC OCCURRENCE AND RESOURCE TEMPERATURE

RESOURCE OCCURRENCE	TEMP	# RESOURCES		SN	MEQ	T	RFL	RFR	GRAV	MAG	AMT	MT	TEL	GEOM	CSAMT	TEM	CSFEM	VES	HEP	DD	BD	PD	IP	SP	RAD	HF	TG	STG	BG	RS	ROW TOTALS
RIFT VALLEY	LOW	1	0	1	0	1	0	1	1	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	1	0	0	0	8	
	MOD	7	0	2	0	0	0	2	1	0	2	0	0	0	1	1	3	1	0	2	0	0	1	0	3	3	0	0	1	23	
	HI	5	2	3	1	2	1	3	2	0	3	2	0	0	0	0	3	2	3	2	0	0	2	0	3	1	2	0	2	39	
	SUBTOTAL	13		2	6	1	3	1	6	4	0	5	2	0	0	1	1	7	3	4	5	0	0	3	0	6	5	2	0	3	70
BASIN AND RANGE	LOW	1	0	0	0	0	0	1	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	0	1	9	
	MOD	2	1	1	0	1	0	1	1	1	2	1	1	0	1	1	1	0	1	1	0	0	1	1	2	1	1	0	1	22	
	HI	3	3	3	2	2	2	3	2	2	2	2	0	1	1	2	3	1	3	3	0	1	2	2	2	2	1	1	1	49	
	SUBTOTAL	6		4	4	2	3	2	5	4	4	5	3	1	1	2	4	5	1	4	4	0	1	3	3	4	4	3	1	3	80
INTRUSIVE VOLCANIC	LOW	2	0	0	0	1	0	1	2	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	1	1	0	0	0	9	
	MOD	7	1	1	0	1	0	3	2	1	1	0	1	0	0	0	3	0	1	0	0	0	0	1	3	4	0	2	0	25	
	HI	3	0	1	1	1	1	2	2	2	2	0	0	0	1	2	3	0	3	2	1	0	1	1	1	3	0	0	2	32	
	SUBTOTAL	12		1	2	1	3	1	6	6	3	3	0	1	0	1	2	7	1	4	2	1	0	2	2	5	8	0	2	2	66
EXTRUSIVE VOLCANIC	LOW	4	0	0	0	2	1	1	0	0	0	0	0	0	0	1	2	1	1	0	0	0	0	0	1	2	0	0	1	13	
	MOD	19	2	3	1	6	5	8	4	6	4	3	1	0	3	0	11	4	5	3	1	0	7	1	9	7	1	1	8	104	
	HI	24	7	12	4	8	5	15	14	5	10	6	0	0	4	6	15	8	9	8	1	1	5	2	10	12	1	2	8	178	
	SUBTOTAL	47		9	15	5	16	11	24	18	11	14	9	1	0	7	7	28	13	15	11	2	1	12	3	20	21	2	3	17	295
BASINS	LOW	3	1	0	0	1	0	1	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	3	3	0	0	0	12	
	MOD	6	0	1	1	2	1	3	1	1	4	4	2	0	1	1	3	1	1	1	0	0	1	0	4	2	1	0	0	34	
	HI	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	5	
	SUBTOTAL	10		1	1	1	4	1	5	2	1	4	4	2	0	1	2	5	1	2	1	0	0	1	0	7	6	1	0	0	51
TOTAL	LOW	11	1	1	0	5	1	5	4	1	1	0	0	0	0	3	6	2	3	1	0	0	1	0	5	8	1	0	2	51	
	MOD	41	4	8	2	10	6	17	9	9	13	8	5	0	6	3	21	6	8	7	1	0	10	3	21	17	3	3	10	208	
	HI	36	12	19	8	14	9	24	21	9	17	10	0	1	6	10	25	11	18	15	2	2	10	5	16	19	4	3	13	303	
COLUMN TOTALS		88	17	28	10	29	16	46	34	19	31	18	5	1	12	16	52	19	29	23	3	2	21	8	42	44	8	6	25	562	

TABLE V

PERCENT UTILIZATION OF GEOPHYSICAL METHODS BY GEOLOGIC OCCURRENCE AND RESOURCE TEMPERATURE

RESOURCE OCCURRENCE	TEMP	# RESOURCES	SN	MEQ	T	RFL	RFR	GRAV	MAG	AMT	MT	TEL	GEOM	CSAMT	TEM	CSFEM	VES	HEP	DD	BD	PD	IP	SP	RAD	HF	TG	STG	BG	RS
RIFT VALLEY	LOW	1	0	100	0	100	0	100	100	0	0	0	0	0	0	100	0	100	0	0	0	0	0	0	100	0	0	0	0
	MOD	7	0	29	0	0	0	29	14	0	29	0	0	0	14	14	43	14	0	29	0	0	14	0	43	43	0	0	14
	HI	5	40	60	20	40	20	60	40	0	60	40	0	0	0	0	60	40	60	40	0	0	40	0	60	20	40	0	40
	ALL	13	15	46	8	23	8	46	31	0	38	15	0	0	8	8	54	23	31	38	0	0	23	0	46	38	15	0	23
BASIN AND RANGE	LOW	1	0	0	0	0	0	100	100	100	100	0	0	0	0	100	100	0	0	0	0	0	0	0	0	100	100	0	100
	MOD	2	50	50	0	50	0	50	50	50	100	50	50	0	50	50	50	0	50	50	0	0	50	50	100	50	50	0	50
	HI	3	100	100	67	67	67	100	167	67	67	67	0	33	33	67	100	33	100	100	0	33	67	67	67	67	33	33	33
	ALL	6	67	67	33	50	33	83	67	67	83	50	17	17	33	67	83	17	67	67	0	17	50	50	67	67	50	17	50
INTRUSIVE VOLCANIC	LOW	2	0	0	0	50	0	50	100	0	0	0	0	0	0	0	50	50	0	0	0	0	50	0	50	50	0	0	0
	MOD	7	14	14	0	14	0	43	29	14	14	0	14	0	0	0	43	0	14	0	0	0	0	14	43	57	0	29	0
	HI	3	0	33	33	33	33	67	67	67	67	0	0	0	33	67	100	0	100	67	33	0	33	33	33	100	0	0	67
	ALL	12	8	17	8	25	8	50	50	25	25	0	8	0	8	17	58	8	33	17	8	0	17	17	42	67	0	17	17
EXTRUSIVE VOLCANIC	LOW	4	0	0	0	50	25	25	0	0	0	0	0	0	0	25	50	25	25	0	0	0	0	0	25	50	0	0	25
	MOD	19	11	16	5	32	26	42	21	32	21	16	5	0	16	0	58	21	26	16	5	0	37	5	47	37	5	5	42
	HI	24	29	50	17	33	21	63	58	21	42	25	0	0	17	25	63	33	38	33	4	4	21	8	42	50	4	8	33
	ALL	47	19	32	11	34	23	51	38	23	30	19	2	0	15	15	60	6	32	23	4	2	26	6	43	45	4	6	36
BASINS	LOW	3	33	0	0	33	0	33	0	0	0	0	0	0	0	33	33	0	33	0	0	0	0	0	3	3	0	0	0
	MOD	6	0	17	17	33	17	50	33	33	67	67	33	0	17	17	50	17	17	17	0	0	17	0	67	33	17	0	0
	HI	1	0	0	0	100	0	100	100	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	100	0	0	0
	ALL	10	10	10	10	40	10	50	20	10	40	40	20	0	10	20	50	10	20	10	0	0	10	0	70	60	10	0	0
SUBTOTAL	LOW	11	9	9	0	45	9	45	36	9	9	0	0	0	0	27	55	18	27	0	0	0	9	0	45	73	9	0	18
	MOD	41	10	20	5	24	15	41	22	22	32	20	12	0	15	7	51	15	20	17	2	0	24	7	51	41	7	7	24
	HI	36	33	53	22	39	25	67	58	25	47	28	09	3	17	28	69	31	50	42	6	6	28	14	44	53	11	8	36
	TOTAL	38	99	32	11	33	18	52	39	22	35	20	6	11	14	18	59	22	33	26	3	2	24	9	48	50	9	7	28

TABLE VI

SUMMARY OF THE PERCENT UTILIZATION OF GEOPHYSICAL METHODS BY GEOLOGIC OCCURRENCE AND RESOURCE TEMPERATURE

RESOURCE OCCURRENCE	TEMP	# RESOURCES	SN	MEQ	T	RFL	RFR	GRAV	MAG	AMT	MT	TEL	GEOM	CSAMT	TEM	CSFEM	VES	HEP	DD	BD	PD	IP	SP	RAD	HF	TG	STG	BG	RS
RIFT	LOW	1	D	A	D	A	D	A	A	D	D	D	D	D	D	D	A	D	A	A	D	D	D	D	D	A	D	D	D
VALLEY	MOD	7	D	B	D	D	D	B	C	D	B	D	D	D	C	C	B	C	D	B	D	D	C	D	B	B	D	D	C
	HI	5	B	A	C	B	C	A	B	D	A	B	D	D	D	D	A	B	A	B	D	D	B	D	A	C	B	D	B
	ALL	13	C	B	C	C	C	B	B	D	B	C	D	D	C	C	A	C	B	B	D	D	C	D	B	B	C	D	C
BASIN AND	LOW	1	D	D	D	D	D	A	A	A	A	D	D	D	D	A	A	D	D	D	D	D	D	D	D	A	A	D	A
RANGE	MOD	2	A	A	D	A	D	A	A	A	A	A	A	D	A	A	A	D	A	A	D	D	A	A	A	A	A	D	A
	HI	3	A	A	A	A	A	A	A	A	A	A	D	B	B	A	A	B	A	A	D	B	A	A	A	A	B	B	B
	ALL	6	A	A	B	A	B	A	A	A	A	A	C	C	B	A	A	C	A	A	D	C	A	A	A	A	A	C	A
INTRUSIVE	LOW	2	D	D	D	A	D	A	A	D	D	D	D	D	D	D	A	A	D	D	D	D	A	D	A	A	D	D	D
VOLCANIC	MOD	7	C	C	D	C	D	B	B	C	C	D	C	D	D	D	B	D	C	D	D	D	D	C	B	A	D	B	D
	HI	3	D	B	B	B	B	A	A	A	A	D	D	D	B	A	A	D	A	A	B	D	B	B	B	A	D	D	A
	ALL	12	C	C	C	B	C	A	A	B	B	D	C	D	C	C	A	C	B	C	C	D	C	C	B	A	D	C	C
EXTRUSIVE	LOW	4	D	D	A	A	B	B	D	D	D	D	D	D	D	B	A	B	B	D	D	D	D	D	B	A	D	D	B
VOLCANIC	MOD	19	C	C	C	B	B	B	C	B	C	C	C	D	C	D	A	C	B	C	C	D	B	C	B	B	C	C	B
	HI	24	B	A	C	B	C	A	A	C	B	B	D	D	C	B	A	B	B	B	C	C	C	C	B	A	C	C	B
	ALL	47	C	B	C	B	C	A	B	C	B	C	C	D	C	C	A	C	B	B	C	C	B	C	B	B	C	C	B
	LOW	3	B	D	D	B	D	B	D	D	D	D	D	D	D	B	B	D	B	D	D	D	D	D	C	C	D	D	D
BASINS	MOD	6	D	C	C	B	C	A	B	B	A	A	B	D	C	C	A	C	C	C	D	D	C	D	A	B	C	D	D
	HI	1	D	D	A	A	D	A	A	D	D	D	D	D	D	D	A	D	D	D	D	D	D	D	D	A	D	D	D
	ALL	10	C	C	B	B	C	A	C	C	B	B	C	D	C	C	A	C	C	C	D	D	C	D	A	A	C	D	D
	LOW	11	C	C	D	B	C	B	B	C	C	D	D	D	D	B	A	C	B	C	D	D	C	D	B	A	C	D	C
SUBTOTAL	MOD	41	C	C	C	C	C	B	C	C	B	C	C	D	C	C	A	C	C	C	C	D	C	C	A	B	C	C	C
	HI	36	B	A	C	B	B	A	A	B	B	B	D	C	C	B	A	B	A	B	C	C	B	C	B	A	C	C	B
	TOTAL	88	C	B	C	B	C	A	B	C	B	C	C	C	C	C	A	C	B	B	C	C	C	C	B	A	C	C	B

A = utilization ≥ 50% B = 25% ≤ utilization < 50% C = 0% < utilization 25% D = 0%

TABLE VII

DISTRIBUTION OF ARTICLES AS A FUNCTION OF COUNTRY

LOCATION	
ALGERIA	1
AUSTRALIA	3
BRAZIL	1
CANADA	9
CARIBBEAN SEA	1
CHILE	3
CHINA	1
COSTA RICA	3
CZECHOSLAVAKIA	2
DENMARK	1
EAST GERMANY	2
EGYPT	2
EL SALVADOR	2
ENGLAND	1
ETHIOPIA	4
FIJI	0
FRANCE	10
GREECE	2
HUNGARY	3
ICELAND	13
INDIA	10
INDONESIA	9
IRAQ	0
ISRAEL	0
ITALY	30
JAPAN	21
KENYA	2
MEXICO	21
NEW GUINEA	1
NEW ZEALAND	12
NICARAGUA	2
PERU	1
PHILIPPINES	2
PORTUGAL	2
REPUBLIC OF DJIBOUTI	0
ROMANIA	0
SPAIN	1
SWITZERLAND	1
TAIWAN	7
THAILAND	1
TURKEY	6
UGANDA	1
USA	340
USSR	25
WEST GERMANY	4
YEMEN ARAB REPUBLIC	0
YUGOSLAVIA	1

TABLE VIII

THE SEVEN COUNTRIES REFERENCED THE MOST
WITHIN THE AUGMENTED BIBLIOGRAPHY*

COUNTRY	NO. REFERENCES	PERCENTAGE OF TOTAL NO. OF REFERENCES
USA	340	59
ITALY	30	5
USSR	25	4
JAPAN	21	4
MEXICO	21	4
ICELAND	13	2
NEW ZEALAND	12	2
ELSEWHERE	113	20
TOTAL	575	100

* Based on the GEOREF bibliography and the articles from Geoelectric and Geothermal Studies (Adams, 1976).

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March 20, 1985

D. Fernando Huertas
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Dear Fernando:

Transmitted herewith is the reference section of the report, "The Application of Geophysical Methods to Geothermal Exploration", by Mike Wright and myself. We apologize for the late transmittal. I believe that this completes the delivery of all portions of the report.

In editing this list of references we have noted several minor errors in the reference as cited in the text. In most cases the error is in the year of publication as compared to the year of presentation at a symposium. A list of these corrections is attached so you may correct the text citation as you deem necessary. Figures and tables were counted in order to arrive at a page number for the reference citation.

Sincerely,

Howard P. Ross

Howard P. Ross
Section Head/Geophysics

HPR/jp

enclosure

cc: P. M. Wright

LIST OF CORRECTIONS FOR REFERENCE CITATIONS

Chapter	Page and Paragraph in Chapter	Previous Citation	Corrected Citation
III.	Pg. 31, ¶1	Smith et al., 1975	Smith et al., 1976
	Pg. 33, ¶2 (follows Fig. 14)	Hartley, 1980	delete reference
V.	Pg. 6, ¶1	Fox, 1980	Fox, 1978
	6, ¶1	Hulen, 1980	Hulen, 1978
	Pg. 9,¶3	Sass et al., 1980	Sass et al., 1981
	Pg. 11, ¶4	Winkler (1979)	Winkler (1979), Winkler and Nurr (1979; 1982)
VI.	Pg. 10, ¶2	Sass et al. (1980)	Sass et al. (1981)
	10, ¶2	Wilson and Chapman (1982)	Wilson and Chapman (1980)
	Pg. 14, ¶2	LeShack, 1982	LeShack and Lewis, 1983
	Pg. 24, ¶1	Ward and Sill (1982)	Ward and Sill (1984)
	Pg. 29, ¶3	Hoover (1978)	Hoover et al. (1978)
	29, ¶4	Sandberg and Hohmann, 1981	Sandberg and Hohmann, 1982
	Pg. 32, ¶5	Fitterman, 1978	Fitterman, 1978; 1979
	Pg. 33, ¶1	Corwin and Hoover, 1978	Corwin and Hoover, 1979
	33, ¶2	Corwin and Hoover, 1978	Corwin and Hoover, 1979
	33, ¶3	Zablocki, 1981	Zablocki, 1977
	33, ¶3	Zablocki, 1981	Zablocki, 1976
	33, ¶3	Sill (1982)	Sill (1981; 1982a,b,c,)
	Pg. 36, ¶1	Lian and McEvilly, 1979	Liaw and McEvilly, 1979
	36, ¶3	Hunt and Lattan, 1982	Hunt and Latter, 1982
	Pg. 38, ¶1	Hill et al. (1981)	Hill et al. (1982)
	Pg. 44, ¶2	Mabey (1980)	Mabey et al. (1978)
	44, ¶2	Couch et al. (1981)	Couch et al. (1982a)
	44, ¶2	Flovenz and Georgeson, 1980	Flovenz and Georgeson, 1982
VI.	Pg. 44, ¶2	Palnasson, 1976	Palmasson, 1976
	Pg. 47, ¶3	Couch et al. (1981)	Couch et al. (1982b)
	47, ¶3	Williams and Finn (1981)	Williams and Finn (1982)
	Pg. 48, ¶4	Glenn et al., 1981	Glenn et al., 1982
	Pg. 49, ¶1	Glenn and Hulen, 1979	Glenn and Hulen, 1979a,b
	49, ¶1	Glenn and Ross, 1981	Glenn and Ross, 1982
	Pg. 57, ¶1	Glenn and Hulen, 1979	Glenn and Hulen, 1979a,b
	57, ¶1	Glenn and Hulen, 1979	Glenn and Hulen, 1979a,b
	Pg. 59, ¶1	Gal'perin (1980)	Gal'perin (1973)

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RESOURCE OCCURRENCE	TEMP	# RESOURCES	SN	MEQ	T	RFL	RFR	GRAV	MAG	AMT	MT	TEL	GEOM	CSAMT	TEM	CSFEM	VES	HEP	DD	BD	PD	IP	SP	RAD	HF	TG	STG	BG	RS
RIFT VALLEY	LOW	1	0	1	0	1	0	1	1	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	1	0	0	0
	MOD	7	0	2	0	0	0	2	1	0	2	0	0	0	1	1	3	1	0	2	0	0	1	0	3	3	0	0	1
	HI	5	2	3	1	2	1	3	2	0	3	2	0	0	0	0	3	2	3	2	0	0	2	0	3	1	2	0	2
	SUB-TOTAL	13	2	6	1	3	1	6	4	0	5	2	0	0	1	1	7	3	4	5	0	0	3	0	6	5	2	0	3
BASIN AND RANGE	LOW	1	0	0	0	0	0	1	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	0	1
	MOD	2	1	1	0	1	0	1	1	1	2	1	1	0	1	1	1	0	1	1	0	0	1	1	2	1	1	0	1
	HI	3	3	3	2	2	2	3	2	2	2	2	0	1	1	2	3	1	3	3	0	1	2	2	2	2	1	1	1
	SUB-TOTAL	6	4	4	2	3	2	5	4	4	5	3	1	1	2	4	5	1	4	4	0	1	3	3	4	4	3	1	3
INTRUSIVE VOLCANIC	LOW	2	0	0	0	1	0	1	2	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	1	1	0	0	0
	MOD	7	1	1	0	1	0	3	2	1	1	0	1	0	0	0	3	0	1	0	0	0	0	1	3	4	0	2	0
	HI	3	0	1	1	1	1	2	2	2	2	0	0	0	1	2	3	0	3	2	1	0	1	1	1	3	0	0	2
	SUB-TOTAL	12	1	2	1	3	1	6	6	3	3	0	1	0	1	2	7	1	4	2	1	0	2	2	5	8	0	2	2
EXTRUSIVE VOLCANIC	LOW	4	0	0	0	2	1	1	0	0	0	0	0	0	0	1	2	1	1	0	0	0	0	0	1	2	0	0	1
	MOD	19	2	3	1	6	5	8	4	6	4	3	1	0	3	0	11	4	5	3	1	0	7	1	9	7	1	1	8
	HI	24	7	12	4	8	5	15	14	5	10	6	0	0	4	6	15	8	9	8	1	1	5	2	10	12	1	2	8
	SUB-TOTAL	47	9	15	5	16	11	24	18	11	14	9	1	0	7	7	28	13	15	11	2	1	12	3	20	21	2	3	17
BASINS	LOW	3	1	0	0	1	0	1	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	3	3	0	0	0
	MOD	6	0	1	1	2	1	3	1	1	4	4	2	0	1	1	3	1	1	1	0	0	1	0	4	2	1	0	0
	HI	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
	SUB-TOTAL	10	1	1	1	4	1	5	2	1	4	4	2	0	1	1	4	1	2	1	0	0	1	0	7	6	1	0	0
TOTAL	LOW																												
	MOD																												
	HI																												
	TOTAL	88	17	28	10	29	16	46	34	19	31	18	5	1	12	15	51	19	29	23	3	2	21	8	42	44	8	6	25

Howard,

just a note to let you know progress is being made on my statistical analysis of the data. Enclosed is a nearly completed summary sheet of the application of the various methods as a function of geologic setting and resource temperature. I think a more meaningful presentation is the "% usage of methods" (ie, $\frac{\text{\# of times a method is used in a particular resource type}}{\text{total \# of resource types reviewed}}$).

Here's a statistic for you, for the areas I reviewed 6.9 geophysical methods (out of a possible 27) were used per resource area (out of a possible 88 areas)! More exciting trivia later.

I hope to rough out my report by the end of this coming week. Will that time frame cause you problems? Also I still have your report. It's on my desk should you need it.

Dick

24-JAN-85

PS. I think I have ~110 hrs invested into this project. I would like to hire Craig B. for about 1 hour to help me check my transfer of numbers from 1 table to another. Is that a problem?

RCW