

decade, ever since these techniques have been perfected. The similarity between these methods is demonstrated by transform theory, but there still are differences, starting with the definition of chargeability and frequency effect. Frequency effect is measured in the presence of an inducing current, which causes slight differences in IP response that are probably due to ion mobility, ion flow diffusion, and the chemical environment in rocks. There are also important contrasts in electrical field equipment and electronic instruments that are used to measure the time and frequency related IP effects.

Investigation of the small differences between pulse and frequency methods can be done using hysteresis measurements. In these experiments it is necessary to control precisely the inducing current level.

This report reviews and compares the two basic types of IP methods, and gives observational results with comments on their significance.

THE METAL FACTOR

M-23

John S. Sumner

Since the introduction of the metal factor concept to induced-polarization prospecting nearly 15 years ago, the parameter has been both extolled and condemned. Some have noted that it represents the total charge in conductivity of a rock, that it normalizes the polarization effect, and that it is diagnostic of the presence of mineralization. Others have said that it merely exaggerates resistivity contrasts, has no physical significance, and is compounded by occasional bothersome coupling effects.

Although the metal factor was originally defined as a normalized frequency effect, it has a good physical definition in the pulse system, where it is the specific capacity or quadrature conductance. It is readily shown that the metal factor X forms a primary relationship between induced current dipole moment P and the exciting electric field E within earth materials as is given by

$$P = -XE$$

Model results and field surveys show the usefulness and of the sometimes misleading aspects of the metal factor.

It is concluded that the metal factor is usually a useful parameter in IP surveying and that it has a good fundamental meaning. However the term can be abused if its significance is overemphasized in unmineralized areas of high IP background or very low resistivity.

DEEP PENETRATING AIRBORNE TURAIR EM SYSTEM

M-24

R. H. Pemberton, H. O. Seigel,
and R. A. Bosschart

The Turair system represents a major advance in

airborne electromagnetic prospecting as it provides more than double the potential detection depth of any other present electromagnetic system, while maintaining excellent resolution and conductivity discrimination. Sulfide zones with their apex well below 500 ft subsurface have been readily detected by the Turair system and subsequently confirmed by diamond drilling.

The system, which can be described as a fixed-source, semi-airborne, gradient measuring device, employs a large transmitting loop on the ground as primary source. The horizontal gradients of amplitude and phase of the vertical or horizontal magnetic field are measured from the air by helicopter, along traverse lines across the source, and perpendicular to the regional geological strike.

The Turair method is particularly suitable for the detailed, deep investigation of structures having geologically favorable characteristics, or magnetic expression suggesting favorable geology. Because of its potential depth of exploration it can be successfully employed in areas of deep sedimentary cover, deep weathering, or tall tree cover (tropical areas), or in areas where shallower exploration has established the presence of ore bodies and a deeper search is desired.

There are a large number of areas within the United States and Canada where Turair will have a definite application.

THE APPLICATION OF GEOPHYSICS TO GEOTHERMAL AREAS IN MEXICO

M-25

L. Del Castillo G. and J. H. Sandoval O.

The growth of geothermal plants in the world is due to the development of geological structure containing endogene vapor. The two problems faced by geophysicists in the exploration for geothermal areas are one, to detect the volcanic pattern and two, to obtain some idea of the economic significance of the explored area.

Prior to 1950, no attempts had been made to apply geophysical techniques to the search for geothermal zones in the neovolcanic belt in Mexico. The Institute of Geophysics at the National University (I.G. of N.A.U.M.) was employed by the Instituto de Investigaciones de la Industria Electrica (I.I.E.) of the Federal Commission of Electricity, Mexican Government Agency, to study the possibility of devising a geophysical attack which would be of assistance in their exploration program based on resistivity surveying (dc methods). This study resulted in developing a method of making use of potential fields and their techniques controlled by the seismic refraction method. This particular approach has been adopted in recent years by the I.I.E. and I.G. in the exploration which they are carrying out in Mexico.

Although some geophysical methods used in research have been successfully applied, there are some as-

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the Negritos-Ixtlan which create additional. The rugged of the more powerful. However, as illustrated with uplift gravity and magnetics some type of small a. Some eight holes were area (depths down rocks, affording a from the geophysical station amount to 100 (2 percent) are c. Through this structure and plant site

GEOTHERMAL THE SALTON T

Tsai Meide

Growing interest in energy, coupled with geothermal energy for production, spurred the geothermal energy San Trough. California complementary and to be optimal for low-amplitude gravity anomalies, apparently of the sediments by geothermal gradient anomalies have been employed Schlumberger geophysical depths of 1-2 miles to elaborate the geothermal such as conductivity with temperature in discovery that some Imperial Valley are high heat-flow zones the faults apparently rising from great permeable zone.

Corroboration of thermal and resistivity with some degree the validity of the development target which will be soon

prospecting as it provides potential detection depth of magnetic system, while resistivity and conductivity decrease with their apex well below and readily detected by the method confirmed by diamond

be described as a fixed-current measuring device. A loop on the ground as a function of amplitude of horizontal magnetic field by helicopter, along traverse and perpendicular to the

particularly suitable for the detection of structures having magnetic characteristics, or magnetic anomalies in geologically favorable geology. Because of the fact that it can be successfully used in areas with deep sedimentary cover, deep water (tropical areas), or in areas where exploration has established a deeper search is

of areas within the United States which will have a definite

GEOPHYSICS TRENDS IN MEXICO

J. H. Sandoval O.

plants in the world is the geological structure concerning two problems faced by Mexico for geothermal areas: the pattern and two, to the economic significance of the

had been made to apply research for geothermal energy in Mexico. The Instituto Geológico y Minero de México (I.G.M.) and the Instituto de Investigaciones Científicas y Tecnológicas (IIE) of the Federal Government have been active in the discovery of devising a geophysical method of assistance in their resistivity surveying method. It resulted in developing a geophysical method and their resistivity surveying method. It has been adopted in recent years in the exploration which

methods used in research. There are some as-

of the Negritos-Ixtlan area in the state of Michoacán which create additional problems for the geophysicist. The rugged terrain increases the cost of use of the more powerful geophysical methods such as seismic. However, as illustrated by results, fractures associated with uplift terrain may lower the overburden gravity and magnetics of the area sufficiently to permit some type of small ambiguities.

Some eight holes were then drilled through the covered area (depths down to 400 m) and into the volcanic rocks, affording a good confirmation of the results from the geophysical work. The costs of the power station amount to \$2 million of which only \$40,000 (2 percent) are costs for the geophysical investigation. Through this comparatively small expenditure it was possible to choose the best location for structure and plant site.

GEOTHERMAL EXPLORATION IN THE SALTON TROUGH, CALIFORNIA

M-26

Tsvi Meidav and R. W. Rex

Growing interest in local, nonpolluting sources of energy, coupled with the increasing attractiveness of geothermal energy for dual utilization of power and desalination, spurred this study of the potentialities for geothermal energy in the northern portion of the Salton Trough, California. A multipronged approach, using complementary geophysical techniques has been found to be optimal for the purpose.

Low-amplitude gravity anomalies have been found to be useful indicators of location of geothermal anomalies, apparently due to partial metamorphism of the sediments by rising plumes of hot water. Geothermal gradient measurements in 100-300 ft holes have been employed to delineate the anomalies. Inverse Schlumberger resistivity soundings to effective probing depths of 1-1.5 miles were employed to corroborate the geothermal gradient information, inasmuch as conductivity increases essentially linearly with temperature in a nonsaturate electrolyte. The discovery that some hitherto unmapped faults in the Imperial Valley are spatially related to the abnormally high heat-flow zones gives rise to the hypothesis that the faults apparently serve as conduits of hot water rising from great depth, and spreading out through a permeable zone.

Corroboration of the geophysically derived geothermal and resistivity data is provided from correlation with some deep petroleum drill holes, verifying the validity of the approach. A number of prime development targets have been discovered, some of which will be soon tested.

OCEANOGRAPHY SESSIONS

INFLUENCE OF SHIP DYNAMICS ON SATELLITE NAVIGATION

O-2

Hal H. Bybee, Jr. and John M. Hughes

Pitch and roll is one possible source of error in an integrated marine navigation system. A theoretical analysis of the influence of pitch and roll on the four beam doppler sonar, gyrocompass, and Navy navigation satellite system receiver combination in an integrated marine navigation system is measured by single degree of freedom inclinometers. Typical sets of data from three different vessels are presented in both the time domain and the frequency domain so that the relationships predicted by the theoretical analysis may be observed. This information is related not only to the marine navigation problem, and the doppler sonar error attributable to a lack of pitch and roll knowledge, but also to the analysis of data from other sensors attached to the vessel. This analysis is also extended to evaluate the error introduced into individual satellite fixes in a nonintegrated system by the lack of knowledge of ship dynamics.

INTEGRATED MARINE NAVIGATION EVALUATION BY ELECTRONIC POSITIONING

O-3

R. Unger, M. J. Long, W. Hicks, and G. M. Gilbert

An eleven-line, 435 nm seismic survey is simulated off the Texas Gulf Coast for evaluation of doppler sonar/gyro/satellite navigation using hyperbolic electronic positioning as a reference. The Raydist beta net features a coverage of minimum variation lane widths and almost perpendicular intersections of the hyperbolas. Sky-wave interference in this area is minimum, and due to the station configuration there is no coastal interference. Maximum electronic positioning accuracy is further maintained by having the seismic lines follow the lines of constant phase difference as closely as possible. Raydist positioning accuracy is better than 25 ft for the entire survey and is checked against known fixed positions. The water depth variation stretches over the entire doppler sonar bottom tracking range. The survey design allows for extensive line intersection evaluation.

Part of the test survey is analyzed on a shotpoint-by-shotpoint basis. Analysis of the real-time data shows the differences in latitude and longitude and the variation in doppler sonar and gyro behavior along the lines. The sea test confirms the reliability of satellite position fixes and shows that they can be used for calibration and monitoring of the dead-reckoning sensors in open sea. Post-mission processing of recorded data by means of variance-weighted correction results in considerable improvement in position accuracy.