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GEOLOGICAL AND GEOPHYSICAL EVALUATION OF THE WHITE SAGE FLAT AND WEST COVE FORT GEOTHERMAL PROSPECTS, MILLARD COUNTY, UTAH

prepared by

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PREFACE

White Sage Flat and West Cove Fort, the two prospects discussed in this report, lie in an area with great geothermal potential. All the available evidence indicates that there is a local heat source here, probably a cooling magma body; that the two prospects are underlain by excellent reservoir rocks with high permeabilities and with additional fluid communication to depth provided by several systems of faults; and that there are adequate volumes of water in the subsurface to sustain a large geothermal power production project.

It is possible to stand in the foothills of the Pavant Range and, looking out over the Beaver Graben or the Pavant Valley, count at least 10 separate volcanic flows less than a million years old. Some are so fresh that grasses and sagebrush have yet to root on their black jagged surface. Not all the ascending magmas broke through the surface, either. At the northern edge of the West Cove Fort prospect is a small, well-defined dome in Pleistocene sediments and basalt flows: a perfect manifestation of a magma emplaced at shallow depth. At Cove Fort, the geographic center of the geothermal area, there is no obvious doming but there are other manifestations.

At least a score of places from White Sage Flat to Sulphurdale, warm fumes vent from cavities into the atmosphere. Water wells in Dog Valley less than a thousand feet deep produce water that is almost boiling (190-195°F.). The known area characterized by high temperature gradients is huge: at least 96 square miles of 100+$^{\circ}$C/km and at least 60 square miles of 200+$^{\circ}$C/km gradients. The actual anomaly size is not known since we have no data much further east than Cove Fort. There is a large elongated magnetic low centered near Cove Fort probably due to the demagnetization of the crust by the heat of magmatic intrusion. There is abundant microearthquake activity of just the kind that would accompany the intrusion of a magma or its contraction during cooling: microearthquakes originating from rock with fracture surfaces measured in meters or at most tens of meters. There are several magnetotelluric anomalies in the area. This is an important clue in geothermal exploration because of the strong dependence of the resistivity of water saturated rock on temperature.

Just as crucial to the economic success of a geothermal project is the presence of good reservoir rocks and structure. At White Sage Flat and West Cove Fort we have a thick (probably greater than 4,000 feet) section of predominately carbonate strata overturned and thrusted into position. The rocks subjected to this process have become thoroughly fractured. Underlying this block is another section of similar predominately carbonate strata. Both the thrusted rocks and those underlying them have been faulted by two sets of faults roughly perpendicular to each other. One set of faults trends almost N-S and the other set ENE. These faults could provide abundant fluid volumes from the zone of heating to geothermal wells tapping the highly permeable formations and the faults themselves.

The primary conclusion of this report is that both the White Sage Flat and West Cove Fort prospects should be drilled with deep tests to establish the existence of a geothermal resource in the area.

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(in pocket)

SUMMARY

1. The geologic and geophysical information indicate there is a local heat source in the area between White Sage Flat and Sulphurdale. The White Sage Flat and West Cove Fort geothermal prospects are hot and derive their heat from this source. The lithologic and structural conditions underlying White Sage Flat and most of West Cove Fort are very favorable for the existence of a large volume, high permeability geothermal reservoir.

2. The geologic structure of White Sage Flat is an overturned section of Paleozoic and Mesozoic strata, mostly carbonates, thrusted into position from the northwest over an upright section of similar strata topped by the Jurassic Navajo formation. The thrusted beds dip to the northwest at $\sim 18^{\circ} - 40^{\circ}$.

3. The northeastern sections of West Cove Fort are of a similar geology to White Sage Flat, being approximately 5 miles down strike from that prospect. The rest of the West Cove Fort prospect is covered with alluvium and basalt flows and how much of the prospect is underlain by these Paleozoic and Mesozoic formations is not known.

4. Shallow ($\sim$ 250 ft.) temperature holes show gradients of 400 and 293°C/km (21.9 and 16.1°F/100 ft.) in Section 24, T. 24S, R. 7W. and Section 19, T. 24S, R. 6W. at White Sage Flat. These are two of the highest gradients measured in the entire Cove Fort geothermal area. The extreme eastern sections of White Sage Flat have lower gradients of $\sim$ 55°C/km (3.0°F/100 ft.).

5. Shallow temperature holes at West Cove Fort show 200 - 230°C/km (11 - 12.6°F/100 ft.) gradients in the eastern sections of the prospect. Gradients fall off to about 40°C/km (2.2°F/100 ft.) in the southwest part of the area with over half of the prospect characterized by gradients greater than 100°C/km (5.5°F/100 ft.).

6. Magnetotelluric (MT) data indicate a large conductivity anomaly at West Cove Fort surrounding an east-west fault running through the middle of the prospect.

7. There is no magnetotelluric conductivity anomaly at White Sage Flat. This is not unexpected because most stations located there were near faults which interfered with the telluric field.

8. There is a linear zone of microearthquake activity running through the West Cove Fort prospect roughly coincident with the MT-detected fault. There is considerable microearthquake activity at White Sage Flat particularly in the eastern part of the prospect. Depths to hypocenters are roughly 2.5 - 5.0 km. The main microearthquake activity in the area is a large cluster of events ~2 miles east of Cove Fort.

9. There is a large (>500 gamma) magnetic low centered just south of Cove Fort elongated in a westerly direction through the West Cove Fort prospect. This low is a result of deep crustal phenomena, possibly heating due to intrusion of magma at depth.

10. The available gravity data are of a regional nature and say little about the nature of the heat source or reservoir conditions at White Sage Flat or West Cove Fort.

11. The only geochemical information for the area are a 124 ppm silica concentration measurement made in 1908 on waters from the Sulphurdale mine and the fact that siliceous sinter is presently being deposited at the same location.

12. There has been fairly continuous volcanic activity (basaltic) since the Pleistocene on a N15E trend running through the area from the Cove Fort Volcano north to Ice Springs Crater. There is a rhyolite flow exposed near Tabernacle Hill and several rhyolite flows in the Mineral Mountains.

13. There are numerous sulphur prospect pits in the area and sulphur being mined at Sulphurdale, where sulphur is being deposited by fluids and gases at the present time. There are also several fluorspar prospects in the area.

14. The high precipitation on the permeable volcanic rocks of the Tushars probably provides sufficient hydraulic head and fluid volumes to offset the depletion of

reservoir that might occur under large scale geothermal extraction from strata beneath the thrust plane at White Sage and West Cove Fort.

15. The permeabilities of strata within the beds above the thrust at White Sage and West Cove Fort are probably very high due to fracturing and the possible development of solution porosity in the predominantly carbonate formations.

16. The thrust plane, several sub-vertical faults striking parallel to bedding, and a major vertical N-S fault along the west edge of White Sage could prove to be major conduits of fluids, whether penetrated directly by wells or as pathways for water movement from underlying rocks into the dipping strata of the thrusted block. The same is true at West Cove Fort.

17. The depth to the thrust plane beneath White Sage Flat and West Cove Fort is not known with much certainty. It could lie anywhere from 3,500 - 10,000 feet. It is possible, but seems unlikely, that there could be another thick thrust sheet beneath the one seen at the surface. The preferred model discussed in the text is 4,500 - 5,500 feet to the thrust, and a possible thinner (1,000 - 2,000 feet) thrust sheet beneath it with upright Paleozoic formations in the autochthonous block.

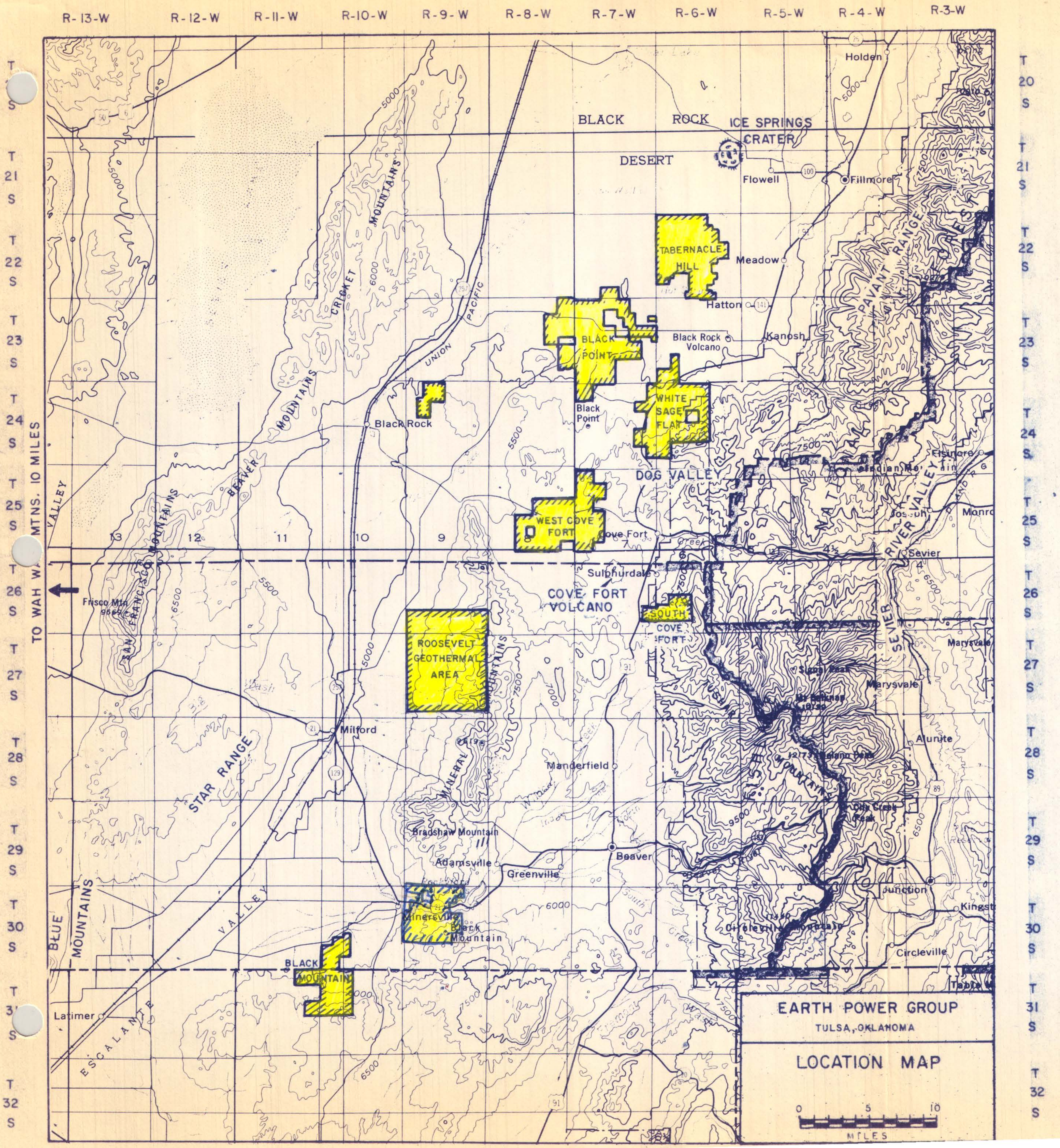
18. The Cove Fort geothermal area lies at the intersection of several structural trends: The NE-SW trend of the Sevier Orogeny thrusts; the N15E trend of Pleistocene and recent volcanoes with their associated fracture system; the N-S to N15E trend of range front block faulting from White Sage to Dog Valley to Sulphurdale and down the Beaver Valley graben; the E-W Clear Creek trend through Cove Fort and the West Cove Fort prospect to the north end of the Mineral Mountains; and the E-W trend of Tertiary granitic intrusions from Marysavle to the Mineral Mountains to the Star Range.

GEOLOGY

Introduction

The West Cove Fort and White Sage Flat geothermal prospects lie in an area with a long history of tectonic activity. Until the early Cretaceous the area was near the eastern edge of the Cordillerian Miogeosyncline in western Utah. The platform area of thin Paleozoic sediments lay in central and eastern Utah and the eugeosyncline in Nevada. A major orogeny began near the Jurassic-Cretaceous transition and thrusted the miogeosynclinal strata eastward. This thrusting episode was complete by Late Cretaceous or earliest Tertiary. A period of relative quiet occurred between the cessation of thrusting and the Miocene. Then began a period of great volcanic activity in the region with the largest local volcanic center being near Marysvale. Block faulting and tilting of the Pavant Range may have begun at this time and apparently continues to the present.

At the close of the Miocene the Mineral Mountain granite was emplaced and uplifted. The Pliocene in the immediate area of the prospect was not particularly active tectonically or volcanically. Rhyolites were extruded in the Mineral Mountains ~ 0.8 - 0.5 m.y. ago. Basalt flows are exposed in the area which show that minor volcanic activity has been fairly continuous from the Pleistocene to the present time.


R-13-W
R-12-W
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TO WAH WAH MTNS. 10 MILES
BLACK ROCK DESERT
ICE SPRINGS CRATER
Holden
Flowell
Fillmore
Meadow
Hatton
Kanosh
Black Rock Volcano
TABERNACLE HILL
BLACK POINT
Black Point
WHITE SAGE FLAT
UNION PACIFIC
CRICKET MOUNTAINS
Black Rock
PAVANT RANGE
DOG VALLEY
WEST COVE FORT
Cove Fort
Sulphurdale
COVE FORT VOLCANO
SOUTH COVE FORT
Fillmore
Joseph
Monroe
Sevier
SEVIER RIVER VALLEY
Marysvale
ROOSEVELT GEOTHERMAL AREA
MINERAL MOUNTAINS
Frisco Mtn 9660
SAN FRANCISCO MOUNTAINS
BEAVER
STAR RANGE
Milford
Manderfield
Bradshaw Mountain
Adamsville
Greenville
Beaver
TUSHAR MOUNTAINS
Alunite
Junction
Kingston
Circleville
Minersville
Black Mountain
BLACK MOUNTAIN
BLUE MOUNTAINS
ESCALANTE VALLEY
Latimer
EARTH POWER GROUP
TULSA, OKLAHOMA
LOCATION MAP
0 5 10
MILES

Pre-Tertiary Stratigraphy and Structure

The prospect areas in Paleozoic times lay in an area of miogeosynclinal sedimentation. The foreland or platform area lay to the east in central and eastern Utah. The trough deepened westward into western Nevada. Within the miogeosynclinal area a thick section of limestones, dolomites and clean sandstones was deposited. To the west there were increasing amounts of shale, dirty sandstones, chert, and volcanic rock being deposited. In the platform area to the east a thin and incomplete Paleozoic section was laid down. Near the West Cove Fort prospect in the southern Pavant Range the contact between the Cambrian and pre-Cambrian is not exposed, and the exposed sedimentary section begins with the Cambrian Tintic Quartzite. Above this the miogeosynclinal sediments total $\sim$12,200 feet (Crosby, 1959) and represent every period from Cambrian to Triassic. There are unconformities within this sequence but none of them are as significant as those to the east in the shelf areas.

The Triassic Moenkopi is the last of the miogeosynclinal formations found in the area. Above it lie the Shinarump Conglomerate, the Chinle Formation (both Triassic and both probably non-marine). The youngest formation below the major angular unconformity developed in the Cretaceous is the eolian Jurassic Navajo Formation.

In the late Jurassic or early Cretaceous began a major orogeny involving a mobile belt that extended from southern Idaho southward through Utah and into Nevada near the southwest corner of Utah. This orogeny continued through the whole of the Cretaceous. This zone has been named the Sevier Orogenic belt by Armstrong (1968) to distinguish it from the Nevadan Orogeny of late Jurassic and early Cretaceous time, and the Laramide Orogeny of late Cretaceous to early Tertiary time. The principal tectonic style of the Sevier Orogeny was the thrusting of miogeosynclinal rocks eastward toward the shelf or platform. This occurred along the entire length of the belt and according to Armstrong (1968) the major thrusts have a minimum of 25 miles of eastward displacement. There was also a significant amount of folding accompanying the thrusting. Armstrong presents considerable evidence that the Sevier thrusts are of the decollement type that occur in the Canadian Rockies and the over thrust belt of Wyoming. And, further, that the sole of the thrusts are primarily in the shales of the Eocambrian or alternately in the shales of the Middle Cambrian. In the southern Pavant Range the main decollement appears to be in the Cambrian Tintic Formation.

Near the prospect area in the Pavant Range the thrusting strikes almost north-south west of Fillmore and swings to a more south-westerly direction near Kanosh and enters the West Cove Fort prospect striking at about Azimuth 245^{o}. Thus the direction of thrusting in the prospect is more southerly than easterly. The thrust and associated rocks are not exposed all the way across the prospect area. Whether the outcrops are terminated by a fault downdropped to the west or are only hidden by the Late Tertiary-Pleistocene rocks is an important question that has yet to be resolved. On either account, the thrust in the Paleozoic rocks can be picked up again at the north end of the Mineral Mountains $\sim$ 7 miles further west. It is possible that the thrust might have been continuous from the northern Mineral Mountains to the Wah Wah Range, or the Blue Mountains, $\sim$ 35 miles to the southwest. The exposed allochthonous block within the West Cove Fort prospect measures $\sim$ 2,100 feet in stratigraphic (Zimmerman, 1961) thickness, but the complete section of Paleozoics is not seen here as it is along strike $\sim$ 8 miles to the northeast at White Sage Flat. There the exposed thrusted block places Cambrian quartzite over Jurassic sandstone and is approximately 10,000 feet thick (Crosby, 1959). The strata within the main allochthonous block dips to the northwest at $\sim$ 25^{o} and the entire section is overturned. Crosby's interpretation that the overturned section is the remnant limb of an overturned anticline seems reasonable in light of the tectonic style of the thrust belt. He also estimates that the minimum displacement along this fault is 15 miles.

In the West Cove Fort prospect the rocks beneath the thrust plate are not exposed. Near Dog Valley the "autochthonous" block dips $\sim$ 10^{o} to the east. The term autochthonous cannot be applied with complete confidence to these rocks since they may be but another slice in a set of imbricate thrust sheets. However, their attitude (rightside up and striking approximately north-south) suggests they may be in place and unthrusted. Also, these strata can be traced essentially continuously to the north where they apparently are indeed part of the autochthonous block (Maxey, 1949; Hickcox, 1971).

The thrust sheet in the vicinity of White Sage Flat is essentially in one piece with only a small amount of faulting within it. The thrust at White Sage Flat is not the only thrust in the area. It has been overridden by at least one other main thrust with a decollement in the Cambrian. An erosional remnant of it lies in T. 24S, R. 8W, Section 7. The main part of this sheet lies farther west in T. 23S, R. 4½W. It appears that this is the main thrust plane of the Sevier Orogeny in the south Pavant Range and not the thrust at White Sage Flat. It appears that the White Sage thrust developed due to the formation of an anticlinal buckle in the strata being thrusted. This fold overturned and a thrust formed at the base of the eastern limb. The main thrust, homologous to the thrusts farther north, formed at the crest of the anticline and overrode the overturned east limb. Thus, the thrust at White Sage is a subsidiary feature of the Sevier Orogeny and is not typical of the style of folding and faulting that occurred in adjacent areas.

Further west near the West Cove Fort prospect, the thrust exposed at White Sage Flat is not seen due to erosion and covering by volcanics and alluvium. What is seen here is the upper thrusted block of White Sage faulted by several faults trending parallel to the strike of the bedding. The fault planes lie in the Devonian and between the Pennsylvanian Oquirrh and the Permian Kaibab Formations. Zimmerman has mapped these as thrusts with the upper plate to the north. However, to account for the missing strata the sense of motion must be opposite to that shown by him and the northern side in fact downthrown. As mentioned earlier the entire section exposed near the West Cove Fort prospect is overturned and dips to the north-northwest at $\sim 25^{\circ}$.

Between the prospect area and the Mineral Mountains about 6 miles west no Paleozoic or Mesozoic rocks are exposed. What gravity data there is suggests that the thrust zone extends unbroken across this gap. (However, a more detailed gravity survey could easily reverse this conclusion.) At the north end of the Mineral Mountains the thrusted rocks (principally parts of the Cambrian section) can be seen again. The rocks that have been overthrusted are also Cambrian. From the north end of the Mineral Range the thrust belt once again resumes its predominant north-south trend and the next exposures along this belt are to be found about 40 miles to the southwest in the Blue Mountains.

Post-Cretaceous Geologic History

After the thrusting of the Sevier Orogeny came a period of relative tectonic quiet until the Miocene. During this period, some of the erosional products from the Paleozoic rocks of the thrust sheets were laid down to form the Price River Conglomerate. The lithology, sedimentary structures, and geometry of the formation indicate that the source area for the formation was in the immediate vicinity of the present exposures of Paleozoic and Mesozoic strata. There is also a possibility that with the reduction of relief in the area, equivalents of the North Horn Formation were laid down. However, the only exposure of this formation are $\sim$ 10 miles east of White Sage Flat (T. 24S, R. 4W). These two formations, the Price River and the North Horn, have been dated paleontologically in areas to the north as Late Cretaceous and are the only sedimentary representatives of the time period between the end of the Sevier Orogeny and the Plio-Pleistocene Sevier River Formation that are to be seen in the prospect area. The lithology of the North Horn Formation east of White Sage Flat is predominately sandstones and siltstones, but shales and limestones become more common to the north (Crosby, 1959). Paleoecological studies and the lithologic Character of the North Horn indicate that at the end of the Cretaceous the area had much lower relief and lay much closer to sea level than it does now.

Faulting

Basin and Range style block faulting was initiated in the area sometime in the Tertiary and continues until the present. Although there is little direct evidence for the exact timing of this faulting at White Sage Flat or West Cove Fort, the similarity in style and degree to other areas nearby where paleotological and stratigraphic data exists suggests that it began in the Miocene. The normal faulting is most developed south of White Sage Flat on the east side of Dog Valley south toward Cove Fort. The parallel faults trend ~ N15E and have broken the Paleozoic and Mesozoic section in a step-like pattern down thrown side to the west. A major branch of this system forms the western edge of White Sage Flat. This fault cuts through the upper thrust sheet at White Sage. The other faults in the system apparently only cut the lower block of strata and die out before reaching White Sage Flat. The normal fault that does cut through the prospect area is offset ~ 2½ miles west of the main fault zone. The strata cut by the normal faulting east of Dog Valley dip to the east at about 10-15 degrees.

Igneous Activity

In the general vicinity of the prospect areas there has been a sequence of volcanic activity since the Miocene. This sequence is summarized in the following table. Most of this activity is much too old and had its source too far away to be of geothermal interest today.

Table of Igneous Activity

Geologic Unit	Age	Reference
Ice Springs Crater	<4000 Yr.	Hoover, 1974
Tabernacle Hill	24,000 - 10,000 Yr.	Hoover, 1974
Cove Fort Volcano	~ Same as Tabernacle Hill	
Pavant Butte	128,000 - 75,000	Hoover, 1974
Beaver Ridge and Kanosh	920,000 - 536,000	Hoover, 1974
Mineral Range Rhyolite	800,000 - 500,000	Nash, 1976
Cove Creek Basalts	2 Flows Pre-Sevier River 1 Flow Post-Sevier River	Zimmerman, 1961
Mineral Range Stock	15.5 ± 1.5 m.y.	Park, 1967
Mt. Belknap Rhyolite	18 m.y.	Anderson, et al, 1975
Tushar Qtz Monzonite	25 m.y.	Basset, et al, 1963
Bullion Canyon Volcanics	29.7 m.y.	Armstrong, 1970

The Bullion Canyon Volcanics came from an eruptive center near Marysvale 30 miles southeast of White Sage Flat. This series was then intruded by quartz monzonite.

The Mt. Belknap Volcanics were laid down on the deeply eroded surface of the Bullion Canyon Volcanics. Their source was also southeast of the prospect area.

West of the area the Mineral Mountain stock was emplaced at shallow depths $\sim$ 15.5 m.y. B.P. The Mineral Mountain stock was uplifted (possibly contemporaneously with the block faulting of Cove Fort - Dog Valley) and eroded. Rhyolite flowed out onto the eroded surface of the Mineral Mountains at $\sim$ 0.5 - 0.8 m.y. B.P. A small rhyolite flow also outcrops at White Mountain near Tabernacle Hill and it may be of similar age.

Several basalt flows exist in the West Cove Fort area that must be early Pleistocene (or Late Pliocene) judging by their stratigraphic position. Two are pre-Sevier River Formation and one is post-Sevier River. More recently, Tabernacle Hill was active with two flows: one before and one after Lake Bonneville time. The Cove Fort Volcano, whose flows cover much of the southern half of the West Cove Fort prospect, appears to be about the same age as Tabernacle Hill judging by the degree of erosion and development of vegetation. And finally, there is Ice Springs Crater, just north of Tabernacle Hill, which is probably less than 10,000 years old.

The continuing development of sulphur mineralization in the area between Dog Valley and Sulphurdale is perhaps a manifestation of recent subsurface igneous activity. Warm H_2S gas vents to the atmosphere at many places along this trend. This sulphur may be a primary emanation from a magma that did not break the surface.

Structural Trends

In the vicinity of White Sage Flat and West Cove Fort, there are several structural trends that converge or cross. Their geothermal significance is not known but they mark the area as one of persistent tectonic activity.

Perhaps the most obvious one is that displayed at White Sage Flat and West Cove Fort where the thrusting is developed. Rocks both in the thrust sheet and lower block strike NE-SW and dip to the NW. This is about 45° to the main thrusts of the Sevier Orogeny which north and south of the area strike almost N-S. Thus the area apparently records a major bend in the thrusting direction in the Late Cretaceous-Early Tertiary. Gravity data also indicate that the Range Front fault that truncates these strata is subparallel to this NE-SW trend. This fault is not exposed at the surface, being hidden beneath the deposits of the Sevier Desert, but may cross beneath the southern sections of T. 23S, R. 7W south of Black Point.

Another trend equally well displayed is the linear arrangement of basaltic volcanoes which is almost N-S (~N15E). From north to south they are Pavant Butte, Ice Spring Crater, Tabernacle Hill, the Cove Creek Basalt Flows, and the Cove Fort Volcano. Igneous activity along this line has been fairly continuous since at least the early Pleistocene.

Superimposed on these basalt flows are numerous normal faults which form small horsts and grabens in the lava. These small faults can be up to several miles in length and parallel very faithfully the N15E trend of the line of volcanoes themselves. Isotopic studies indicate that these lavas came from the mantle and thus a crustal weakness along this trend has persisted for at least the last 2 million years. Associated with this line of eruptions and faulting is a small gentle anticline in T. 24 and 25S, R. 8W which is a fold in the Sevier River Formation and an overlying basalt. The axis of the anticline is parallel to the trend. This fold is very likely the manifestation of the emplacement of a magma body at shallow depth.

The block faulting of the southern Pavant Range between White Sage Flat and Sulphurdale also trends ~N15E but may be an independent phenomenon not associated with that just discussed. As mentioned above, it is also the site of active sulphur mineralization at the present time. Microearthquake studies show that this trend is still active and there are offsets in Quaternary gravels in the area.

Another trend runs east-west through the area along Clear Creek near Cove Fort. This trend is expressed physiographically in the remarkable straightness of Clear Creek Canyon as it cuts through the Mt. Belknap Volcanics. It's westward extension is not so well displayed but would run through Cove Fort and along the Black Rock Road to the extreme northern end of the Mineral Range. Essentially all the microearthquake activity between Cove Fort and the Mineral Range lies along this line. Also the pronounced magnetic low centered south of Cove Fort is noticeably elongated to the west along this trend. Magnetotelluric stations placed in the West Cove Fort prospect showed considerable evidence of faulting along this line and indicated a conductivity anomaly just south of and parallel to this trend.

A case for another east-west trend might be made. Although generally poorly exposed due to later volcanic cover, the outcrops of Tertiary granitic intrusions form a crude lineation. This trend extends from Marysvale westward through the Tushars where several granitic outcrops can be found to the Mineral Mountain Stock across the Milford Valley to the Star Range. This line lies south of the above mentioned Clear Creek trend. It is old (Middle Tertiary), is poorly displayed, and probably has little or no geothermal significance.

Stratigraphic Summary
(after Crosby, 1959)

Period	Formation	Thickness	Dominant Lithology
Jurassic	Navajo	1742	Sandstone
Triassic	Chincle	274	Sandstone & mudstone
	Shinarump	428	Sandstone
	Moenkopi	1054	Shale, siltstone, limestone
Permian	Kaibab	1193	Limestone, silty sandstone
	Coconino	288	Sandstone
	Pakoon	174	Limestone
Pennsylvanian	Oguirrh	949	Limestone, dolomite
Mississippian	Redwall	273	Limestone
Devonian	Cove Fort	83	Sandstone
	Guilmette	570	Dolomite
	Simonson	239	Dolomite
	Sevy	673	Dolomite
Ordovician	Fish Haven	1000	Dolomite
	Swan Peak/Eureka	178	Sandstone
	Pogonip	1110	Limestone
Cambrian	Herkimer	1153	Limestone, dolomite
	Dugmar	104	Dolomite
	Teutonic	424	Limestone
	Ophir	418	Limestone, shale
	Tintic	1293	Sandstone

Shale	1054	Mostly Triassic Moenkopi
Sandstone	4286	Mostly Jurrassic Navajo and Cambrian Tintic
Limestone	5694)	8280
Dolomite	2586)	
Total	13620	

Geologic Structure at Depth

The geologic structure at White Sage Flat is fairly complicated at the surface and extrapolations to depth are not very tightly constrained, allowing many models that are geologically reasonable. These models fall roughly into three main groups. The main features of the geology at the surface to which the models must conform are:

1) The overturned beds near the exposed edge of the thrust dip at approximately 45° to the north. The thrust cuts through the Kaibab formation at this point.

2) These dips become more shallow ($\sim 18^{\circ}$) moving north to a distance of about 2 miles from the thrust.

3) A normal fault transects the section running parallel to the strike of the beds down dropping the northern side.

4) Where exposed south of White Sage Flat, the section beneath the thrust strikes roughly N-S dipping east at 10-30 degrees and is block faulted downthrown side to the west.

In the first group of models, the thrust parallels or subparallels bedding beneath the area. If the thrust stays in the Kaibab, and the straight line extrapolation of surface dips holds to depth, a deep well in the vicinity of the high gradient wells (T. 24S, R. 6W, Section 19) would intersect the thrust at about 8,000 feet. If the thrust plane deepens to include the Triassic formations above it, the thrust might be intersected at $\sim$9,500 - 10,000 feet. The rocks beneath the thrust might be Devonian carbonates.

In the second group of models the thrust flattens rapidly to the north. A reasonable range of depths to the thrust beneath T. 24S, R. 6W, Section 19, would be from 3,500 feet to 8,000 feet (the depth for thrust parallel to bedding discussed above). Taking an intermediate representative between these extremes, the thrust might lie at 4,500 - 5,500 feet. If the thrust plane does flatten rapidly with depth, a large part of the stratigraphic section would be missing and would probably lie beneath the main thrust north of the target area in smaller imbricate thrusts also composed of overturned beds.

In the third group of models, the main thrust might be underlain by one or more thrusts that have no surface exposure. These lower thrusts might be thin, just shavings off the "top" of the Mesozoic section. Or, they might be thick, in which case they would probably be upright and include much of the Paleozoic and Mesozoic strata. If there is more than one main thrust the depth to the autochthonous block might be anywhere from 8,000 - 20,000 feet. Although the southern Pavant Range has been overridden by at least one other block (erosional remnants of it can be found at White Sage), the tectonic style of the area does not suggest that this was a typical pattern of events. This, however, is not a very compelling case for ruling out the presence of major thrusts beneath the known thrust at White Sage Flat.

The main conclusion that can be drawn from our knowledge of the surface geology is that a wide variety of subsurface structures are possible at White Sage Flat. In planning a geothermal field, it seems essential to know the subsurface geology in more detail than we do now. It is suggested that seismic reflection profiles be run to try and eliminate some of the ambiguity in our present conjectures. The same catagories of models are applicable to the geology of the northeastern portions of the West Cove Fort prospect, but we know even less there due to poor exposure of outcrops.

Despite the above, I'll make a guess at what would be encountered by a deep test at White Sage:

0 - 5,000 ft.	Ordovican Fish Haven to Permian (Pakoon); overturned dipping to the north at $\sim 18^{\circ}$.
Thrust Plane	
5,000 - 7,000 ft.	Permian to Triassic; overturned and dipping to the north.
Thrust Plane	
7,000 ft.-down	Regular upright section, Devonian on down; maybe dipping to the NE at $\sim 20^{\circ}$.

GEOPHYSICS AND GEOCHEMISTRY

Magnetics

The regional magnetic field in the target area is shown in Plate 4. The principal features of this field are:

1) A very large low centered south of Cove Fort. The low has an amplitude of $\sim$5-600 gammas and is elongated in an east-west direction.

2) A high over the granite stock of the Mineral Range. The north end of this range which is thrusted Paleozoics is noticeably without magnetic character.

3) A high over the southern Tushars which is elongated in a NNW direction.

4) A series of minor highs associated with a string of volcanoes that runs N-S west of Kanosh.

The low at Cove Fort is a prominent feature even on a map at a scale of 1:250,000. Associated with this low are several phenomena of geothermal interest. In the immediate vicinity of the low is sulphur mineralization, H_2S emissions and hot waters of the Dog Valley-Sulphurdale trend. Numerous microearthquakes have been detected $\sim$2 miles north of the center of the magnetic low. While the block faulting of the Southern Pavant Range Mountains cuts across the axis of the low, the Clear Creek structural trend coincides with this axis. Where temperature gradient data is available (in the western half of the low) the isograds approximately parallel the contours of the magnetic field, enclosing much of the magnetic anomaly in a zone of 200+^{o}C/km temperature gradient.

Two possible explanations of the source of this anomaly come readily to mind. First, that hydrothermal fluids have extensively altered the magnetic minerals in a large volume of the subsurface. This explanation is supported by the fact that hot waters are known at the present time. Second, the anomaly could be due to large volumes of rock, possibly an intrusive body, at temperatures above the Curie Point.

The magnitude and areal extent of the Cove Fort anomaly, and its relationship to a line of magnetic lows extending from north of the San Francisco Mountains to the Sevier River Valley, indicates that this feature is not due to some local shallow phenomena such as alteration of magnetic minerals or a cooling magma. Indeed, a shallow magma body would have to be huge (> 500 KM^3) to create a magnetic low of several hundred gammas covering 50-75 square miles, assuming any realistic estimate of the susceptibility of the country rock. The feature correlates almost perfectly with the northern boundary of the Tertiary volcanic province of southwestern Utah. North of this line the magnetic anomaly field is smooth with few closures of large amplitude. South of this line the field is complex with numerous closures of moderate to large amplitude and with very strong east-west trends that crosscut the present north-south Basin and Range grain. These anomalies are no doubt due to numerous igneous bodies emplaced throughout the crust only a few of which are exposed in outcrop or can be seen as volcanic flows or vents. The Cove Fort anomaly seems more intimately related to this Tertiary volcanic province than it does to local phenomena of geothermal interest. Because of its apparent association with an older volcanic epoch it does not mean that this feature is unimportant in the context of geothermal exploration in the Cove Fort area. It is a strong east-west feature on a regional scale and may be due to zone in the crust characterized by a significantly shallower depth to the Curie isotherm. Elevation of the Curie isotherm does not necessarily indicate the presence of magma but that in the recent past (perhaps $< 1,000,000$ years) this region was intruded and has yet to cool below 500-600°C.

Microearthquake Data

There are several well-defined microearthquake zones in the prospect area. The most active area lies just east of the town of Cove Fort. Numerous earthquakes were recorded here with an average detected rate of ~9 earthquakes per day. The events are generally shallow: most lie at depths of from 3.0 - 4.5 km with some as shallow as 2 km. The surface geology shows normal faulting of the Paleozoic and Mesozoic strata. First motion data from the earthquake surveys was highly ambiguous and so does not contribute much to our understanding of the stress situation in the subsurface.

There is another well-defined but less active zone at White Sage Flat. The block faulting in the Cove Fort area trends ~ N15E and the White Sage Flat earthquake cluster is virtually on strike with the larger cluster at Cove Fort. There is not much evidence of normal faulting at White Sage comparable to that a few miles to the south and the microearthquake events at White Sage may be manifestations of incipient block faulting in this area. It is also worth noting that the earthquakes at White Sage lie generally east of the heat anomaly there (or at least east of the anomaly as it is known at present).

Another zone of activity is along the Black Rock Road through the West Cove Fort prospect. This linear trend of earthquakes is not as active as the Cove Fort or White Sage zones. This zone lies along the axis of the elongate Cove Fort magnetic low, parallels a fault detected by magnetotellurics and marks an extension of the "Clear Creek" structural trend through the area. There are a few scattered events south of this line in the vicinity of the extinct Cove Fort volcano.

Gravity

There is not very good gravity coverage available for the White Sage Flat and West Cove Fort prospects. The data is generally of a regional character (Cook, et. al., 1975). There is a strong regional gradient from high to low along a traverse from the Sevier Desert across the southern Pavant Range to Marysvale. This regional is due to geologic conditions in the deep crust associated with the transition zone between the Basin and Range and Colorado Plateau. The contours follow the southern Pavant Range as it swings through the White Sage area in a southwesterly direction and then follows in a southerly direction the trend of the Mineral Mountain stock. The gravity low of the Beaver Valley graben does not transect this trend to connect with the low of the Black Rock Desert. This would indicate that there is not a major downdrop of the Paleozoic section in the unexposed interval between the outcrops in the NE part of the West Cove Fort prospect and the north end of the Mineral Range. It must be remembered, however, that the station density in this critical area is very low. Sontag (1965) shows a minor inflection in the gravity field east of Cove Fort that indicates the presence of Paleozoic and Mesozoic strata beneath the volcanics of the Mt. Belknap series. Although he does not show that he has any stations in the area, Sontag also has contoured and named a "Black Point Gravity High" which lies just north of the West Cove Fort prospect. If real, this feature would indicate that Paleozoic and Mesozoic rocks extend beneath the subsurface at least as far north as Sections 19 and 20 of T. 24S, R. 7W.

Temperature Gradient Data

Between Tabernacle Hill and the Cove Fort Volcano, we have shallow temperature data of generally good quality from 47 holes. This information defines a large heat anomaly extending from White Sage Flat south to Sulphurdale and from Section 21, T. 25S, R. 8W, east to $\sim$2 miles east of Cove Fort. The area enclosed within the $100^{\circ}C$/km ($5.5^{\circ}F$/100 ft.) isograd measures $\sim$96 square miles. The area within the $200^{\circ}C$/km ($11^{\circ}F$/100 ft.) isograd measures $\sim$60 square miles.

The heat anomaly as defined by the data at hand is roughly triangular with corners at White Sage Flat, Sulphurdale and Section 21, T. 25S, R. 8W. The northern boundary parallels the outcrops of Paleozoics involved in the Pavant thrust. The eastern boundary is indefinite since we do not have wells that show where the anomaly ends in that direction. The isograds of measured wells, though, sub-parallel the N15E structural trend of the block faulting in the Cove Fort-Dog Valley trend. On the southwest side there is no correlation with surface geology and the gradients fall off fairly smoothly from $\sim 225^{\circ}C$/km to $\sim 35^{\circ}C$/km (12.3 to $2.0^{\circ}F$/100 ft.) in a distance of 2 - 4 miles.

An important hole is #156 in Section 2, T. 25S, R. 7W. This hole showed a gradient of $\sim 188^{\circ}C$/km ($10.3^{\circ}F$/100 ft.) down to a depth of 375 meters where it went isothermal at a temperature of about $90^{\circ}C$. Two wells in Dog Valley (#258 and #255), while not penetrating as deep as this (only 280 meters) produce water from an aquifer at a temperature reported to be $100\text{-}195^{\circ}F$. It appears this aquifer could be the same as that encountered in hole #156 when differences in surface elevation are taken into account. How large an area is underlain by this aquifer is unknown. But, an extensive high temperature aquifer at this high temperature would certainly bias the gradients in shallow holes drilled over it. The huge areal extent of the temperature anomaly and the variety of geologic settings in which holes have been drilled is evidence against the idea that this shallow high temperature aquifer is responsible for the high gradients in the area. The geologic and geophysical data indicate the presence of a local heat source in the area and not merely a hot aquifer deriving its waters from deep circulation in an area of roughly normal geothermal gradients.

The West Cove Fort prospect is characterized by high gradients ($200+^{\circ}C$/km or $11+^{\circ}F$/100 ft.) in its northeastern sections with the gradients falling off to the southwest to a low of $68.5^{\circ}C$/km

($3.8^{O}F/100$ ft.). This fall-off could be due in some degree to thickening of the alluvial fill over the Paleozoic section. This effect increases the area of attractive gradients within the prospect. As presently known, over half of the West Cove Fort prospect has gradients over $100^{O}C/km$ ($5.5^{O}F/100$ ft.).

The White Sage Flat prospect has two of the highest gradients measured in the entire Cove Fort geothermal zone (408^{O} and $293^{O}C/km$ or 22^{O} and $16^{O}F/100$ ft.). These holes are in the western part of the prospect. About 1½ miles ENE of the $293^{O}C/km$ hole is a measured gradient of only $55^{O}C/km$ ($3.0^{O}F/100$ ft.) This abrupt drop should be studied further with intervening holes. Hole #236 ($408^{O}C/km$) lies very close to a N-S fault and the temperature regime may be abnormally high at this point due to fluid circulation in the fault zone. Hole #301 ($283^{O}C/km$) was drilled $\sim$1 mile east to test this hypothesis and its high gradient shows that while the fault may have had some influence on temperatures at hole #236, the anomaly is real and this part of White Sage Flat is definitely hot. More holes should be drilled between this area and Dog Valley to refine our knowledge of the temperature anomaly before picking a site for a deep test.

Magnetotellurics

The broad features of the magnetotelluric data are the following:

1) High resistivities in the southern Pavant Range at White Sage Flat and its extension into the West Cove Fort prospect.

2) High resistivities in along the Dog Valley - Cove Fort block faulting trend.

3) High resistivities in the Mineral Mountain stock and the subsurface extension of hard rock toward the Cricket Mountains.

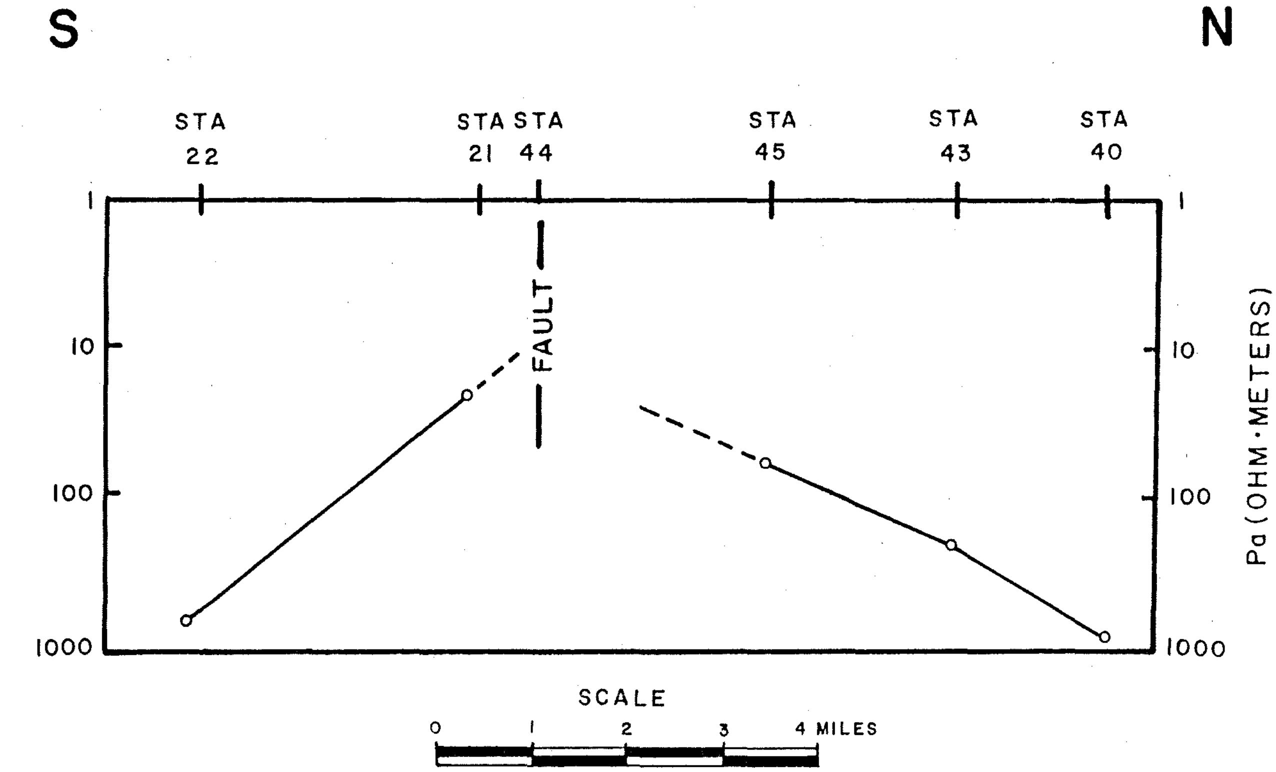
4) Extreme lows in the saline lake deposits of the Black Point area.

5) Extreme lows in the Milford Valley.

None of these broad features are indicative of conductivity anomalies that might be associated with geothermal reservoirs.

In the West Cove Fort prospect, Stations #50, #44, and #5 appear to lie on an east-west fault that has no expression in the surface geology. The microearthquake data indicate that this fault is active. The resistivities of the surface layers decrease dramatically as the fault is approached from either the north or south. Just south of the fault are two stations with very low resistivities (Stations #130 and #21). This situation of a fault zone surrounded by an area of high conductivity is attractive from a geothermal standpoint. The depth of exploration of the MT soundings also decreases near the fault zone due to the conductivity increase. The electrical basement to the north and south of the fault lies about 4,000 feet below the surface. It is possible that basement also exists at approximately the same depth beneath the conductivity anomaly near the fault. However, this speculation remains to be tested.

The MT data at White Sage Flat indicates that there is a fault at the foot of the mountains that runs through Stations #17, #15, and #4, with the downthrown side to the northwest. Assuming that the electrical basement under White Sage Flat is the bedrock complex exposed in the mountains, there appears to be at least 5,000 feet of vertical offset along this fault. (Crosby "1959' estimates a minimum of 5,560 feet). Also, the MT data indicate that the downthrown block may be rotated dipping slightly ($\sim$ 700 ft./mi.)



NORTH – SOUTH PROFILE
ACROSS WEST COVE FORT AREA
SHOWING CHANGES IN Pa AT 100 SEC. PERIOD

to the southeast. The resistivities at the stations in and near the White Sage Flat area are not anomalous. The stations on bedrock show high resistivity sections; and those on the flat show low-moderate resistivities that might be expected of a section of extrusives and alluvium with a high resistivity basement. There is, however, only sparse coverage in the lease area. Station #16 is the only MT station within the lease boundaries that does not appear to be near a fault.

Chemistry

We have essentially no geochemical data for the White Sage Flat and West Cove Fort prospects. Lee (1907) reported 124 ppm silica on waters from the Sulphurdale Mine. Rodriguez (1960) reported that silica is being deposited at present along with sulphur at the same location.

RESERVOIR

Since the subsurface structure is poorly known at White Sage Flat and West Cove Fort, any discussion of the possible reservoir conditions is severely limited. The strata dip to the NNW at 15 - 40 degrees, with the dips in general steepening near the edge of the thrust where exposed. It seems likely that the thrust plane itself dips subparallel to the bedding. The rocks beneath the thrust at White Sage strike ~ N-S and dip to the east at 10 - 30 degrees. This N-S structure of the subthrust rocks though may not be their trend at depth for where exposed east of Dog Valley the strata are involved in minor block faulting that strikes approximately N-S.

Heat-driven water circulation would be strongly affected by the dip of the country rock. A local heat source in contact with strata with moderate dips (25 - 40°) would give rise to circulation patterns that would be parallel to the dipping beds. Fluids would travel up dip and spread laterally along strike and return down dip well away from the source of heat. Which way the strata dip, then, in the potential reservoirs at White Sage and West Cove Fort is very important. Unfortunately, if the main reservoir is below the thrust plane, we do not know the attitude of the rocks.

The thrust fault that underlies the area may act as a barrier or a conduit or be completely neutral to the flow of fluids. Whether it is a barrier or conduit will only be determined by a deep drill test and in either case it would be desirable to penetrate it. If it is a barrier, the higher temperature fluids are likely to be found beneath it. If the thrust plane is a fluid conduit it could be a major source of the large volumes required for power production.

Since the subsurface structure is not well known, statements about the geology of the reservoir must be rather general. A summary of the stratigraphy shows that most (~ 60% of the section is carbonate rock, with sandstone and shales in the minority (~ 30% and 10%, respectively). About two-thirds of the carbonate rocks are limestone.

Outcrops and roadcuts in the White Sage Flat area show a high degree of fracturing and in some places they are brecciated. It may be expected that those beds above the thrust which are overturned are thoroughly fractured. Though solution porosity and permeability may be well developed in thick carbonate sections, above the thrust plane fractures are likely to be the more important fluid channels. This is important in that there is a possibility that the thrust plane cuts under the Triassic formations and perhaps even the Navajo. These Mesozoic strata are predominately sandstones and shales where without the presence of numerous fractures, permeabilities may not be sufficient for an economic geothermal reservoir.

Beneath the thrust (assuming there is not another major thrust plate beneath the area) a deep test would very likely enter Paleozoic strata which are predominately carbonates. Here a combination of moderate solution and moderate fracture permeability would be sufficient to provide the required fluid flows.

At White Sage Flat there is a possibility of vertical circulation along several normal faults that transect the thrust sheet. The two principal vertical faults are the one running N-S parallel to Baker Canyon at the west edge of the prospect and the fault running ENE through the Devonian strata from Baker Canyon. The N-S fault is the site of sulphur deposition which indicates that in the recent past fluids were able to ascend along this zone. Unless a source of sulphur lies above the thrust plane at White Sage it appears that this fault does provide fluid communication from beneath the thrust. If a deep test well does not penetrate the thrust it is still possible that fluids from below thrust might be tapped because of ascent along this vertical fault.

The normal fault running at almost right angles to this N-S fault is down dropped to north and Crosby (1959) shows a dip on the fault of 45^{o}. Whether this fault has significant communication with fluids beneath the thrust is not known but on the Cove Fort 15' quad a prospect pit is marked in the SE corner of Section 20, T. 24S, R. 6W. This location is on the fault. It appears thermal fluids rising along this fault could enter the Mesozoic and Paleozoic section and travel up dip with little resistance if our conclusions about permeabilities in the thrusted block are correct. If this fault is highly permeable it could be a major element of the reservoir providing access to fluids in a large volume of rock whether by drilling through the fault or to the south of it.

Communication with fluids beneath the thrust sheet is important because of the large volumes of water consumed in geothermal power production. The strata beneath the thrust are in contact with the volcanics of the Tushar Mountains. The higher elevations of the Tushars receive considerable precipitation and the high permeability porosity of the volcanic rocks there along with their elevation probably provide the hydraulic head and source fluids to keep the Mesozoic and Paleozoic beds they are contact with saturated. The much smaller surface area of and precipitation on the thrust sheet could mean that there is not sufficient fluid present in this block to provide the required fluid volumes without the supplemental water inflow from deeper horizons. Also, waters from beneath the thrust are likely to be hotter due to their deeper circulation and closer proximity to the heat source, which from present indications lies south in the vicinity of Cove Fort.

There is also a possibility of water traveling up dip from the lake sediments of the Pavant Valley. The thrust block is truncated to the north by range front faulting. The exact location of this cutoff is not known but may lie near the boundary of T. 23S and T. 24S. The surface area of the thrust block in contact with the lake sediments buried alluvial deposits would be large and from all indications the water in this area would be cold. The natural tendency would be for ground water to flow down dip through the strata and out into the valley. With large volumes of water being extracted from the area this flow could be curtailed and if the hydraulic head is essentially eliminated a reverse flow could occur. However, since the geothermal extraction operations at White Sage Flat will probably be 5 or so miles up dip from this area the problem seems negligible and it appears unlikely from what data we have that cold water from the Pavant Valley will degrade the reservoir.

The bedrock geology of the West Cove Fort prospect is not well exposed compared to White Sage Flat. However, the geology of the northeastern sections of the prospect is an extension of the structure at White Sage. If the Kaibab is overturned in Section 11, T. 25S, R. 7W, as Zimmerman has mapped, the main thrust of White Sage must run south of there through Section 14. And if it stays parallel to strike of the exposed beds would run westward through Section 19. The general comments made above regarding the effect of the thrust on reservoir conditions at White Sage apply here at West Cove Fort even though the location of the fault is uncertain. The West Cove Fort area also has several faults similar to the one at White Sage that runs ENE parallel to the strike of the bedding. As mentioned above, these are probably not thrust faults as Zimmerman has mapped them, but appear to be downthrown to the north. And as at White Sage, these faults may prove to be major conduits of geothermal fluids.

Between the known geology of the northeastern sections of West Cove and the north end of the Mineral Range there must be a fairly major structural change. The White Sage thrust fault must terminate in this unexposed interval and the overturned strata associated with it must be truncated. Either the emplacement of the granitic stock or a major N-S fault could accomplish this. The geophysical data at hand are not sufficient to resolve this problem. The temperature gradients are high over to Section 21, T. 25S, R. 8W. Thus, while most of the West Cove Fort prospect looks very promising, most of the prospect is an unknown as far as reservoir conditions are concerned. Seismic reflection data would be very desirable here, more so than at White Sage Flat.

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RECOMMENDATIONS

Deep geothermal test wells should be drilled at White Sage Flat and West Cove Fort. The wells should go to at least 6,000 feet. The geologic and geophysical data on hand indicate that at White Sage Flat the location should be NW SE SE, Section 25, T. 24S, R. 6W. At West Cove Fort the location should be NW NW NE, Section 18, T. 25S, R. 7W. More geophysical work should be done, however, before picking final locations. Temperature gradient holes both shallow ($\sim$300 feet) and of intermediate depth (1,500 feet) should be drilled. And it is strongly recommended that reflection seismic work be done, particularly at West Cove Fort.

Location for additional gradient holes are listed on the attached schedule. Permitting for these holes should begin immediately, particularly for the 1,500 feet holes since institutional delays may run anywhere from 3-6 months. There are many more holes located than will actually be drilled, but all should be permitted so that the supervising geologist will have some flexibility in planning and changing the drilling program as temperatures from the initial suite of holes becomes available.

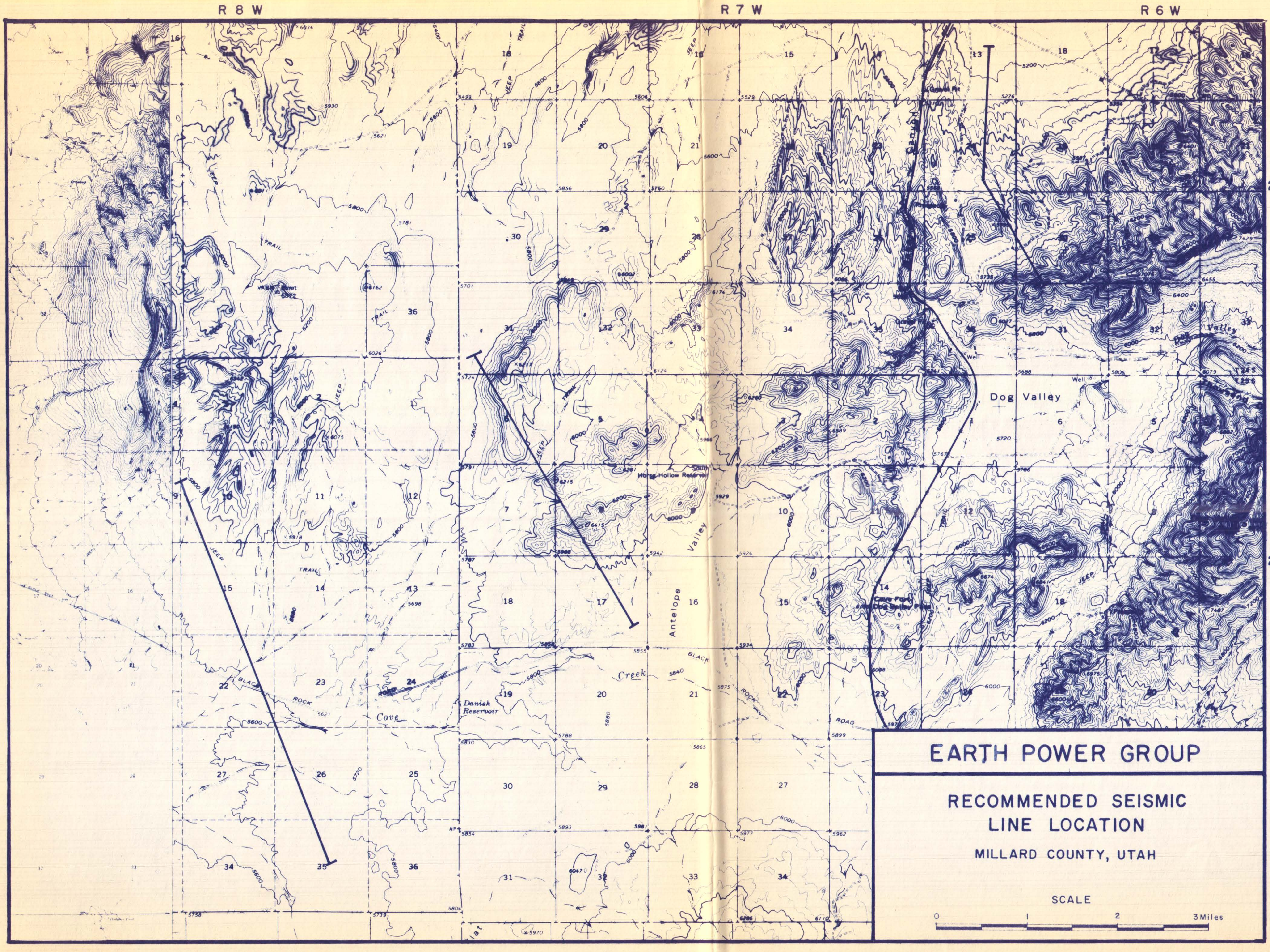
Well locations for the South Cove Fort, Black Rock, Black Mountain and Minersville prospects have been picked and it is recommended that they be permitted at this time. This will greatly expedite the exploration program for these areas.

Priorities for drilling are indicated on the schedule for each prospect. At White Sage Flat priority should be given to locations in the southern sections of the prospect closer to the exposed edge of the thrust and south of the ENE normal fault. At West Cove Fort priority should be given to holes on strike with the Paleozoic strata particularly in the northeastern sections of the prospect. For the unexplored prospects the priorities are very tentative since there we have very little geologic knowledge of the areas.

The recommended seismic profiles are shown on the accompanying map. These lines total approximately 12½ miles. Permitting for the lines across the West Cove Fort prospect should be initiated as soon as possible. The main purpose of the lines is to try and ascertain the attitude of the thrust plane and the orientation of the strata beneath it. At West Cove Fort the westernmost line is very important because we are not sure that reservoir rocks (Paleozoic and Mesozoic strata) underlie the entire prospect area.

Once the results from the shallow holes are available, deep test locations should be chosen and the intermediate depth holes drilled at these sites. From our understanding of the geology at this time, these locations at both West Cove Fort and White Sage Flat should be designed to either intersect the normal faults that parallel the strike of the beds, or be south of these faults toward the exposed edge of the thrust. The rationale for this is that these faults could be major conduits for fluid flow. They could be tapped directly by drilling through them. Or, they could be tapped indirectly by drilling south of them through strata fed by the faults. By drilling south of the faults, there is also a greater likelihood of penetrating the major thrust plane with a 6,000 foot well.

The seismic data will be used primarily for planning the development of the geothermal field and therefore the seismic work might be postponed until the initial deep tests prove the existence of the resource.


EARTH POWER GROUP
RECOMMENDED SEISMIC
LINE LOCATION
MILLARD COUNTY, UTAH
SCALE
0
1
2
3 Miles
R 8 W
R 7 W
R 6 W
Dog Valley
Antelope
Valley
Horse Hollow Reservoir
Danish Reservoir
Cove
Creek
BLACK ROCK
ROAD
JEEP
TRAIL
Well

Shallow Gradient Wells

(300 feet)

Priority Holes Underlined

White Sage Flat

Fee Locations:

Hole #	Township	Range	Section	¼of¼of¼
200	T. 24S,	R. 7W,	Section 13,	NW SE SE
201	T. 24S,	R. 7W,	Section 25,	NW SE NW
202	T. 24S,	R. 7W,	Section 25,	SW SW SE
203	T. 24S,	R. 6W,	Section 19,	SE NW SW
204	T. 24S,	R. 6W,	Section 30,	NW SE NW
205	T. 24S,	R. 6W,	Section 20,	SW NW NW
206	T. 24S,	R. 6W,	Section 18,	NE NE SW
212	T. 24S,	R. 6W,	Section 3,	NW NE SE

BLM Locations:

210	T. 24S,	R. 7W,	Section 23,	SW SW NE

Forest Service Locations:

207	T. 24S,	R. 6W,	Section 20,	SW SE SE
208	T. 24S,	R. 6W,	Section 21,	NE SW NE
209	T. 24S,	R. 6W,	Section 15,	SE SE NW
211	T. 24S,	R. 6W,	Section 16,	SW NE SW
213	T. 24S,	R. 6W,	Section 9,	SW NE SE

West Cove Fort

BLM Locations:

100	T. 24S,	R. 7W,	Section 32,	NE NE SW
101	T. 25S,	R. 7W,	Section 5,	SE NE NE
102	T. 25S,	R. 7W,	Section 4,	SW NE SW
103	T. 25S,	R. 7W,	Section 6,	NW NW NW
104	T. 25S,	R. 7W,	Section 6,	NE SE SE
105	T. 25S,	R. 7W,	Section 7,	NE SE NW
106	T. 25S,	R. 7W,	Section 8,	NE SE NW
107	T. 25S,	R. 7W,	Section 8,	SE SE SE
108	T. 25S,	R. 7W,	Section 9,	NE NE SE

109	T. 25S,	R. 8W,	Section	14,	SW	NW	SE
110	T. 25S,	R. 7W,	Section	18,	SE	SE	NW
111	T. 25S,	R. 7W,	Section	17,	NE	NE	SW
112	T. 25S,	R. 7W,	Section	16,	SE	SE	NW
113	T. 25S,	R. 8W,	Section	22,	SW	SW	SW
114	T. 25S,	R. 8W,	Section	23,	SW	NE	SW
115	T. 25S,	R. 8W,	Section	24,	NE	SW	NW
116	T. 25S,	R. 7W,	Section	19,	NE	NE	SW
117	T. 25S,	R. 7W,	Section	21,	SW	NW	SE
118	T. 25S,	R. 8W,	Section	25,	SE	SE	NW
119	T. 25S,	R. 7W,	Section	30,	NW	SE	SE
120	T. 25S,	R. 8W,	Section	11,	NE	SW	NW
121	T. 25S,	R. 8W,	Section	20,	SW	NE	SW
122	T. 25S,	R. 8W,	Section	28,	SW	SW	SW

South Cove Fort

Forest Service Locations:

300	T. 26S,	R. 6W,	Section	20,	SE	NW	NW
301	T. 26S,	R. 6W,	Section	20,	SW	SW	SW
302	T. 26S,	R. 6W,	Section	29,	NE	SW	NW
303	T. 26S,	R. 7W,	Section	25,	SE	NE	NW
304	T. 26S,	R. 6W,	Section	30,	NW	NW	SW
305	T. 26S,	R. 6W,	Section	30,	SE	SE	SE
306	T. 26S,	R. 7W,	Section	35,	SE	NW	SE

Black Rock

BLM Locations:

501	T. 23S,	R. 9W,	Section	33,	SW	SW	SW
502	T. 24S,	R. 9W,	Section	6,	SW	SE	NW
503	T. 24S,	R. 9W,	Section	5,	NW	NW	SW
504	T. 24S,	R. 9W,	Section	5,	SW	NE	SE
505	T. 24S,	R. 9W,	Section	7,	NE	SW	NW
506	T. 24S,	R. 9W,	Section	8,	SE	NW	NW
507	T. 24S,	R. 9W,	Section	7,	NW	SE	SE
508	T. 24S,	R. 9W,	Section	8,	NE	NE	SE
509	T. 24S,	R. 9W,	Section	18,	SW	NW	SW
510	T. 24S,	R. 9W,	Section	18,	NW	SE	SE
511	T. 24S,	R. 9W,	Section	17,	NW	SE	NW
512	T. 24S,	R. 9W,	Section	16,	NW	SW	NE
513	T. 23S,	R. 9W,	Section	32,	NW	SE	SW

Black Mountain

BLM Locations:

601	T.	30S,	R.	10W,	Section	19,	SE	NE	SE
602	T.	30S,	R.	10W,	Section	20,	NW	SE	SE
603	T.	30S,	R.	10W,	Section	21,	SW	NE	SE
604	T.	30S,	R.	10W,	Section	30,	SE	NW	NW
605	T.	30S,	R.	10W,	Section	29,	SE	NW	NW
606	T.	30S,	R.	10W,	Section	30,	NW	SE	SE
607	T.	30S,	R.	10W,	Section	29,	NW	SE	SE
608	T.	30S,	R.	10W,	Section	28,	SE	NW	SE
609	T.	30S,	R.	10W,	Section	31,	SE	NW	SW
610	T.	30S,	R.	10W,	Section	31,	SW	NE	SE
611	T.	30S,	R.	10W,	Section	32,	SW	NE	SW
612	T.	30S,	R.	10W,	Section	33,	NE	NE	SW
613	T.	30S,	R.	11W,	Section	34,	NE	SW	NW
614	T.	31S,	R.	11W,	Section	4,	SW	NE	SE
615	T.	31S,	R.	11W,	Section	3,	SE	NW	SE
616	T.	31S,	R.	11W,	Section	1,	SW	NW	NE
617	T.	31S,	R.	11W,	Section	1,	NW	NW	SE
618	T.	31S,	R.	10W,	Section	5,	SE	NW	NW
619	T.	31S,	R.	10W,	Section	4,	NW	SE	NW
620	T.	31S,	R.	10W,	Section	5,	NE	SW	SW
621	T.	31S,	R.	11W,	Section	1,	NW	SE	SE
622	T.	31S,	R.	11W,	Section	1,	SW	SW	SW
623	T.	31S,	R.	11W,	Section	11,	NE	SE	NW
624	T.	31S,	R.	11W,	Section	11,	SW	NE	NE
625	T.	31S,	R.	11W,	Section	12,	SW	NE	NE
626	T.	31S,	R.	10W,	Section	7,	NE	NW	SW
627	T.	31S,	R.	10W,	Section	7,	SE	NE	NE
628	T.	31S,	R.	10W,	Section	8,	NW	SW	NE
629	T.	31S,	R.	10W,	Section	8,	NE	NE	NE
630	T.	31S,	R.	10W,	Section	9,	NW	SE	NW
631	T.	31S,	R.	10W,	Section	7,	SE	SE	SW
632	T.	31S,	R.	11W,	Section	14,	NW	NE	SW
633	T.	31S,	R.	11W,	Section	13,	NE	SE	SW
634	T.	31S,	R.	10W,	Section	17,	NE	SE	SW
635	T.	31S,	R.	10W,	Section	15,	SW	SW	NW
636	T.	31S,	R.	11W,	Section	21,	NE	NE	NW
637	T.	31S,	R.	11W,	Section	22,	SE	NW	SW
638	T.	31S,	R.	11W,	Section	23,	SE	NW	SW
639	T.	31S,	R.	11W,	Section	23,	SW	NE	SE
640	T.	31S,	R.	10W,	Section	19,	NW	NE	SE
641	T.	31S,	R.	10W,	Section	20,	NW	SE	SE
642	T.	31S,	R.	10W,	Section	30,	NW	SW	NW
643	T.	31S,	R.	10W,	Section	4,	NE	SE	SE

State Locations:

644	T. 31S, R. 11W, Section 2,	SW NE SW
645	T. 31S, R. 11W, Section 2,	SW NE SE
646	T. 31S, R. 11W, Section 2,	SW NW NW

Minersville

BLM Locations:

701	T. 29S, R. 9W, Section 33,	NE NE NW
702	T. 29S, R. 9W, Section 31,	NW SE SE
703	T. 29S, R. 9W, Section 34,	NE SW SW
704	T. 30S, R. 9W, Section 6,	SE NW NW
705	T. 30S, R. 9W, Section 3,	NE NW NW
706	T. 30S, R. 9W, Section 3,	NW SE NE
707	T. 30S, R. 9W, Section 2,	NW SE NW
708	T. 30S, R. 9W, Section 3,	NW SW SE
709	T. 30S, R. 9W, Section 10,	SW NW NE
710	T. 30S, R. 9W, Section 7,	NE SW SE
711	T. 30S, R. 9W, Section 9,	SW SW SE
712	T. 30S, R. 9W, Section 11,	NW SE SW
713	T. 30S, R. 9W, Section 18,	NW SW NE
714	T. 30S, R. 9W, Section 14,	SE NW NW
715	T. 30S, R. 9W, Section 13,	SE NW NW
716	T. 30S, R.10W, Section 13,	SE NE SE
717	T. 30S, R. 9W, Section 14,	NW SE SE
718	T. 30S, R. 9W, Section 19,	NW SW NW
719	T. 30S, R. 9W, Section 21,	NE SW SW
720	T. 30S, R. 9W, Section 22,	SW SE NW
721	T. 30S, R. 9W, Section 23,	NW SE NW
722	T. 30S, R. 9W, Section 22,	NE SE SW
723	T. 30S, R. 9W, Section 29,	SE SE NE
724	T. 30S, R. 9W, Section 27,	NE SW NE

Intermediate Depth Holes

(1,500 feet)

White Sage Flat

BLM Locations:

Hole #	Township	Range	Section	¼of¼of¼
401	T. 24S,	R. 7W,	Section 23,	SW SW NE

Forest Service Locations:

402	T. 24S,	R. 6W,	Section 20,	SE SE NW
403	T. 24S,	R. 6W,	Section 20,	SW SE SE
404	T. 24S,	R. 6W,	Section 21,	NE SW NE
405	T. 24S,	R. 6W,	Section 15,	SE SE NW
406	T. 24S,	R. 6W,	Section 9,	SW NE SE

West Cove Fort

BLM Locations:

407	T. 25S,	R. 7W,	Section 6,	NW NW NW
408	T. 25S,	R. 7W,	Section 7,	NE SE NW
409	T. 25S,	R. 7W,	Section 18,	SE SE NW
410	T. 25S,	R. 7W,	Section 20,	NE SW NE
411	T. 25S,	R. 8W,	Section 19,	NE NE SW
412	T. 25S,	R. 8W,	Section 24,	NE SW NW
413	T. 25S,	R. 7W,	Section 8,	SE SE SE
414	T. 25S,	R. 7W,	Section 29,	NW SW NE
415	T. 25S,	R. 7W,	Section 30,	NW SE NW
416	T. 25S,	R. 8W,	Section 23,	SE NW NW
417	T. 25S,	R. 8W,	Section 14,	NE SW NW
418	T. 25S,	R. 8W,	Section 22,	NE NE NE
419	T. 25S,	R. 8W,	Section 13,	SE SE NW
420	T. 25S,	R. 8W,	Section 21,	NE SE NE
421	T. 25S,	R. 8W,	Section 28,	NE SE NE
422	T. 25S,	R. 8W,	Section 33,	NW NW SE
423	T. 25S,	R. 8W,	Section 34,	SW SE NE

South Cove Fort

Forest Service Locations:

424	T. 26S, R. 6W, Section 20, SE NW NW
425	T. 26S, R. 6W, Section 29, NE SW NW
426	T. 26S, R. 6W, Section 30, NW NW SW
427	T. 26S, R. 7W, Section 25, SE NE NW
428	T. 26S, R. 7W, Section 35, SE NW SE

Black Rock

BLM Locations:

429	T. 24S, R. 9W, Section 6, SW SE NW
430	T. 24S, R. 9W, Section 5, SW NE SE
431	T. 24S, R. 9W, Section 8, SE NW NW
432	T. 24S, R. 9W, Section 7, NE SW NW
433	T. 24S, R. 9W, Section 8, NE NE SE
434	T. 24S, R. 9W, Section 18, NW SE SE

Black Mountain

BLM Locations:

435	T. 31S, R. 11W, Section 1, NW NW SE
436	T. 30S, R. 10W, Section 31,SE NW SW
437	T. 31S, R. 10W, Section 5, SE NW NW
438	T. 31S, R. 10W, Section 5, NE SW SW
439	T. 31S, R. 10W, Section 8, NW SW NE
440	T. 31S, R. 10W, Section 7, NE NW SW
441	T. 31S, R. 11W, Section 13,NE SE SW
442	T. 31S, R. 10W, Section 17,NE SE SW

State Locations:

443	T. 31S, R. 11W, Section 2, NW SW NE
444	T. 31S, R. 11W, Section 2, SW NE SW

Minersville

BLM Locations:

445	T. 30S,	R. 9W,	Section 6,	SE NW NW
446	T. 30S,	R. 9W,	Section 3,	NW SW SE
447	T. 30S,	R. 9W,	Section 7,	NE SW SE
448	T. 30S,	R. 9W,	Section 9,	SW SW SE
449	T. 30S,	R. 9W,	Section 14,	SE NW NW
450	T. 30S,	R. 9W,	Section 22,	SW SE NW
451	T. 30S,	R. 9W,	Section 21,	NE SW SW

RECOMMENDED SCHEDULE FOR ADDITIONAL GEOPHYSICAL WORK

April '77

1. Submit applications for permits for all gradient holes that require permitting and the seismic lines on BLM land.
2. The applications for the intermediate holes should seek permission to deepen to 6,000 feet.
3. Line up drill rig for shallow holes.
4. Obtain quotes for seismic work.

May '77

1. Begin drilling shallow holes at White Sage Flat and West Cove Fort.
2. Line up drill rig for intermediate holes and arrange for rental of B.O.P. for rig.
3. Obtain quotes and availability of rig for deep test.

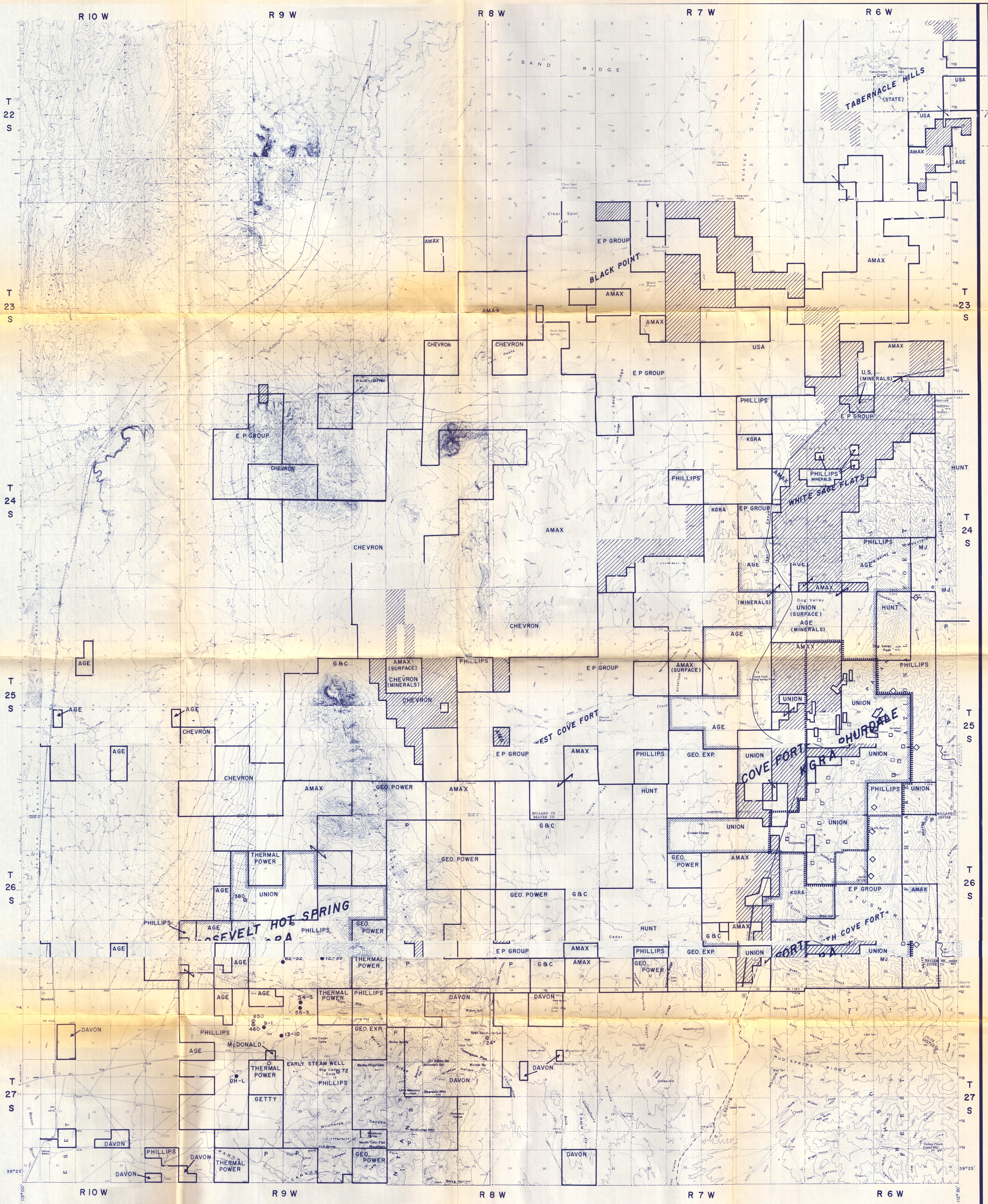
June '77

1. Choose final locations for deep test.
2. Move in rig for intermediate holes.
3. Move shallow rig to the other unexplored prospects.

July '77 Move in rig for deep test at White Sage Flat.

August '77 Move in rig for deep test at West Cove Fort.

September'77 Field seismic crew.



LEGEND

AGE	GEO. EXPL.	PRIVATE PARTY
AMAX	GEO. POWER	USA
CHEVRON	GETTY	THERMAL POWER
E P GROUP	KGRA	KGRA BOUNDARY
FEE LEASE	MJ	UNION UNIT BOUNDARY
G&C	PHILLIPS	

EARTH POWER GROUP
TULSA, OKLAHOMA

LAND STATUS MAP
PROPOSED COVE FORT
TEST LOCATIONS
◇ PHILLIPS
□ UNION

REVISED: March, 1977
SCALE: 1 Inch = 1 Mile
DATE: January, 1976

PLATE 1

R 10 W | R 9 W | R 8 W | R 7 W | R 6 W

QUATERNARY
- Qhs — HOT SPRINGS DEPOSITS
- Qay — RELATIVELY YOUNGER ALLUVIUM
- Qao — RELATIVELY OLDER ALLUVIUM
- Qa/Qal — UNDIFFERENTIATED ALLUVIUM
- Qag — COLLUVIUM & ALLUVIUM
- Qlc — LAKE DEPOSITS

TERTIARY
- Tcg — CONGLOMERATE
- Tsr/TQsr — SEVIER RIVER FORMATION

CRETACEOUS
- Kpr — PRICE RIVER FORMATION

Unconformity

JURASSIC
- Jna — NAVAJO FORMATION

TRIASSIC
- ₮c — CHINLE FORMATION
- ₮s — SHIMARUMP CONGLOMERATE

Unconformity

- ₮m — MOENKOPI FORMATION

PERMIAN
- ₱ka — KAIBAB LIMESTONE
- ₱co — COCONINO SANDSTONE
- ₱pk — PAKOON LIMESTONE

PENNSYLVANIAN
- Poq — OQUIRRH FORMATION

Unconformity

MISSISSIPPIAN
- Mr — REDWALL LIMESTONE

Unconformity

DEVONIAN
- Dg — GUILMETTE FORMATION
- Dsi — SIMONSON DOLOMITE
- Ds — SEVY DOLOMITE

Unconformity

ORDOVICIAN
- Os — ORDOVICIAN-SILURIAN UNDIVIDED
- Ofh — FISH HAVEN DOLOMITE

Unconformity

- Ose — SWAN PEAK/EUREKA QUARTZITE
- Op — POGONIP LIMESTONE

CAMBRIAN
- Ꞓd — DAGMAR LIMESTONE
- Ꞓo — OPHIR FORMATION
- Ꞓt — TINTIC QUARTZITE

IGNEOUS ROCKS
- Qb — BASALT
- Qp/Qr — RECENT & PLEISTOCENE BASALTS (Zimmerman)
- T_2rf — RELATIVELY YOUNGER RHYOLITE FLOWS (Hintze)
- T_2bf — RELATIVELY YOUNGER BASALT FLOW (Hintze)
- Tv — VITROPHYRE (Zimmerman)
- Ta — AUGITE ANDESITE (Zimmerman)
- Th — HORNBLENDE RHYOLITE (Zimmerman)
- Tmb — MT. BELKNAP VOLCANICS (CROSBY)
- Tvmb — MT. BELKNAP VOLCANICS (Hintze)
- Tvdh — DRY HOLLOW LATITE
- Tvbc — BULLIAN CANYON (Hintze)
- Tg — GRANITE
- p€m — GRANITIC & GNESSIC METAMORPHICS

FAULT; DASHED WHERE INFERRED DOTTED WHERE CONCEALED

THRUST FAULT TEETH ON UPPER PLATE

FOLD

15° DIP

25° OVERTURNED BEDS

CROSBY, ZIMMERMAN & HINTZE DISTINGUISH THE VARIOUS TERTIARY VOLCANIC ROCKS DIFFERENTLY. WITHIN THE AREAS MAPPED THE NAMES ASSIGNED BY THE ORIGINAL RESEARCHER HAVE BEEN RETAINED. CROSBY GROUPED ALL THE TERTIARY IGNEOUS ROCKS UNDER THE TITLE "MT. BELKNAP." HINTZE BREAKS THIS UP INTO "DRY HOLLOW", "BULLIAN CANYON" & "MT. BELKNAP". ZIMMERMAN GIVES DESCRIPTIVE NAMES: VITROPHYRE, AUGITE ANDESITE & RHYOLITE.

COVE FORT - SULPHURDALE KGRA
&
ROOSEVELT HOT SPRING KGRA
(N. HALF)
UTAH

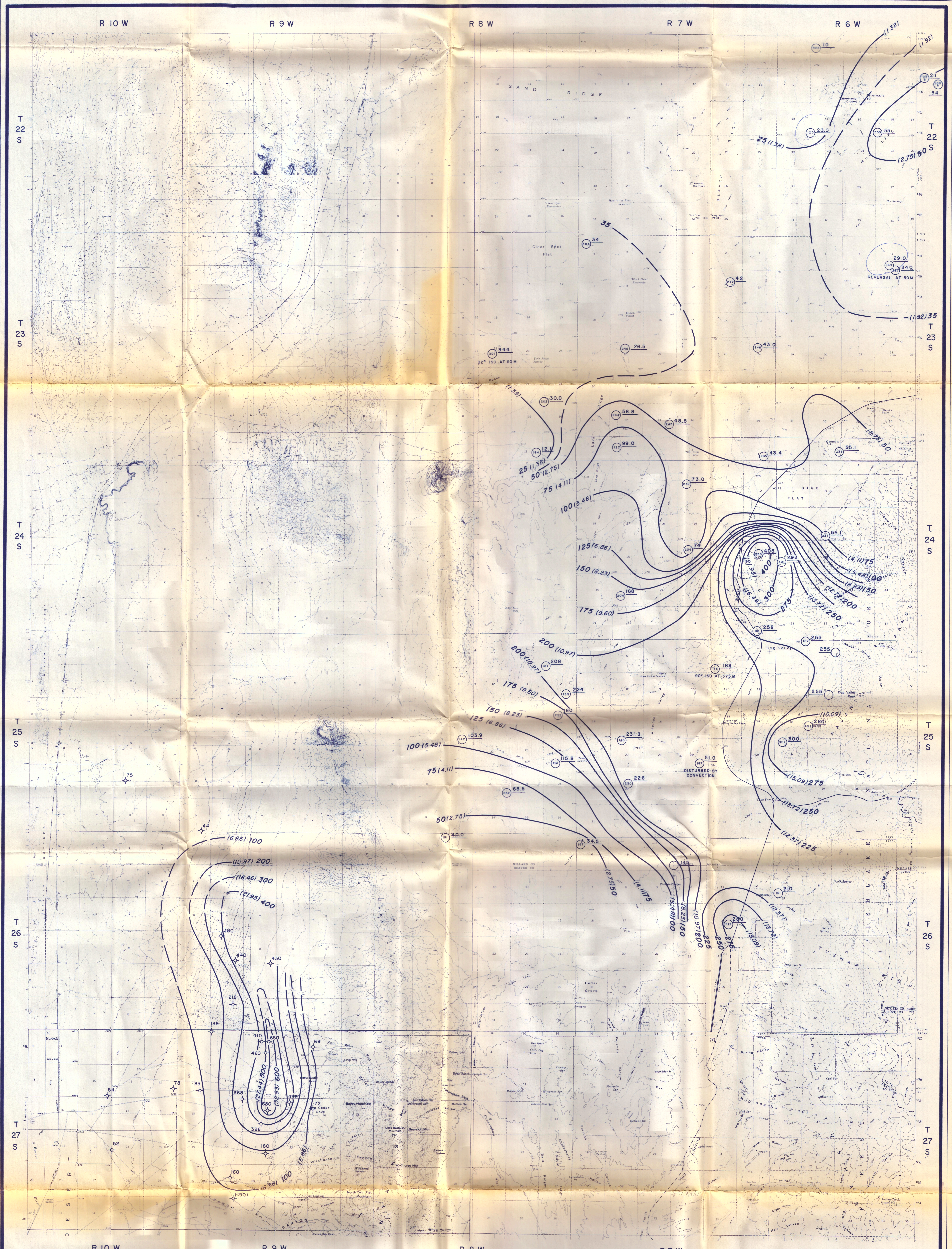
PLATE 2

EARTH POWER GROUP
TULSA, OKLAHOMA

SURFACE GEOLOGY

SOURCES:
CROSBY, ZIMMERMAN, HINTZE, & PETERSON

MARCH, 1977



CONTOURS OF TEMP. GRADIENT IN °C/KM WITH GRADIENT IN °F/100 FT. SHOWN IN PARENTHESES

HOLE # — GRADIENT °C/KM

COVE FORT - SULPHURDALE KGRA
&
ROOSEVELT HOT SPRING KGRA
(N. HALF)
UTAH

PLATE 3

EARTH POWER GROUP
TULSA, OKLAHOMA

COVE FORT, UTAH
TEMP. GRADIENT
°C/KM
(°F/100 FT.)

SCALE: 1" = 1 MILE   DATE: FEBRUARY, 1977

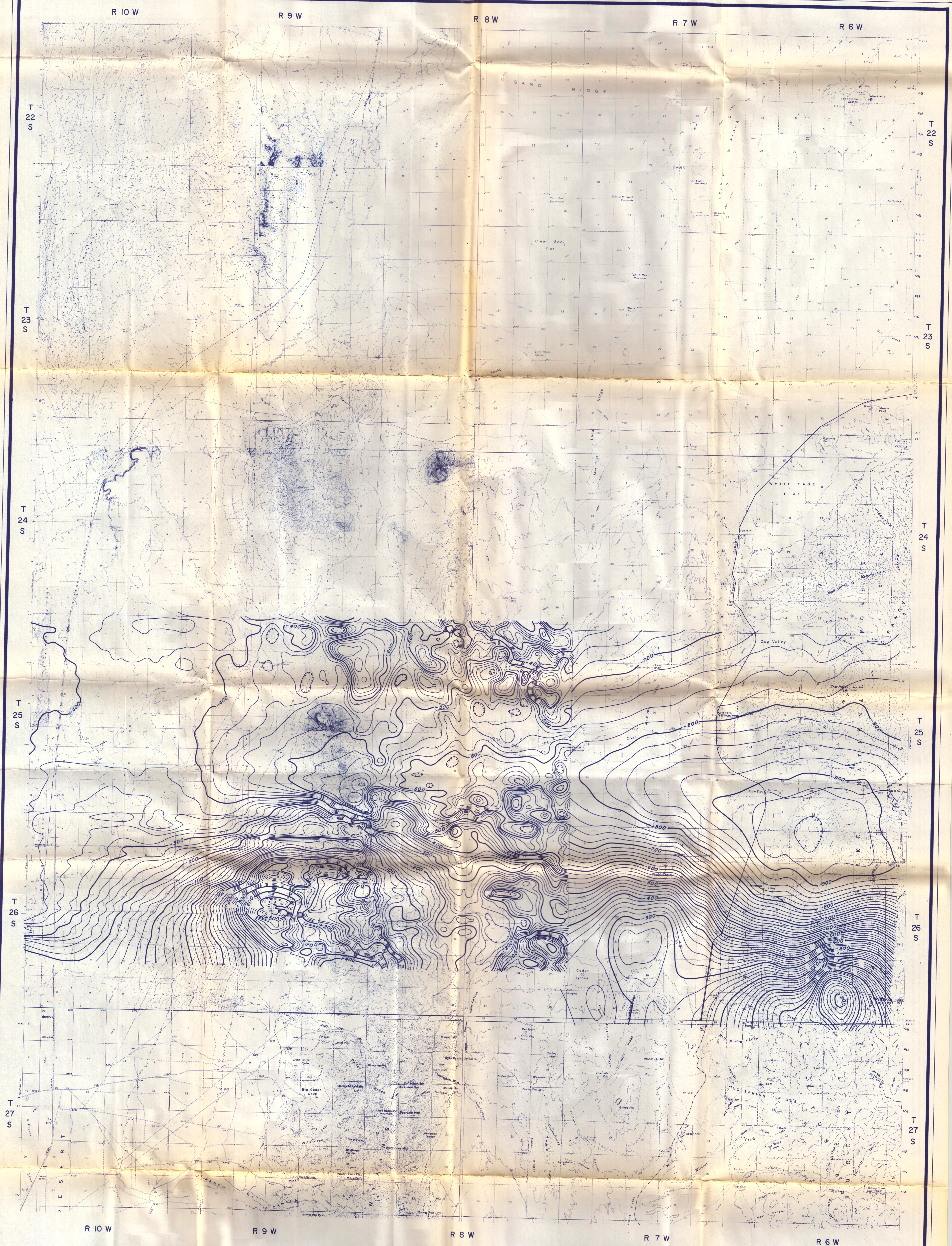


PLATE 4

EARTH POWER GROUP
TULSA, OKLAHOMA

AERO MAGNETIC MAP
MILLARD & BEAVER CO'S., UTAH

WESTERN AREA FLOWN AT
1000 FT. ABOVE SURFACE

EASTERN AREA FLOWN AT
12000 FT. ABOVE SEA LEVEL

SOURCE: UNIVERSITY OF UTAH

SCALE: 1" = 1 MILE DATE: 1976

COVE FORT - SULPHURDALE KGRA
&
ROOSEVELT HOT SPRING KGRA
(N. HALF)
UTAH

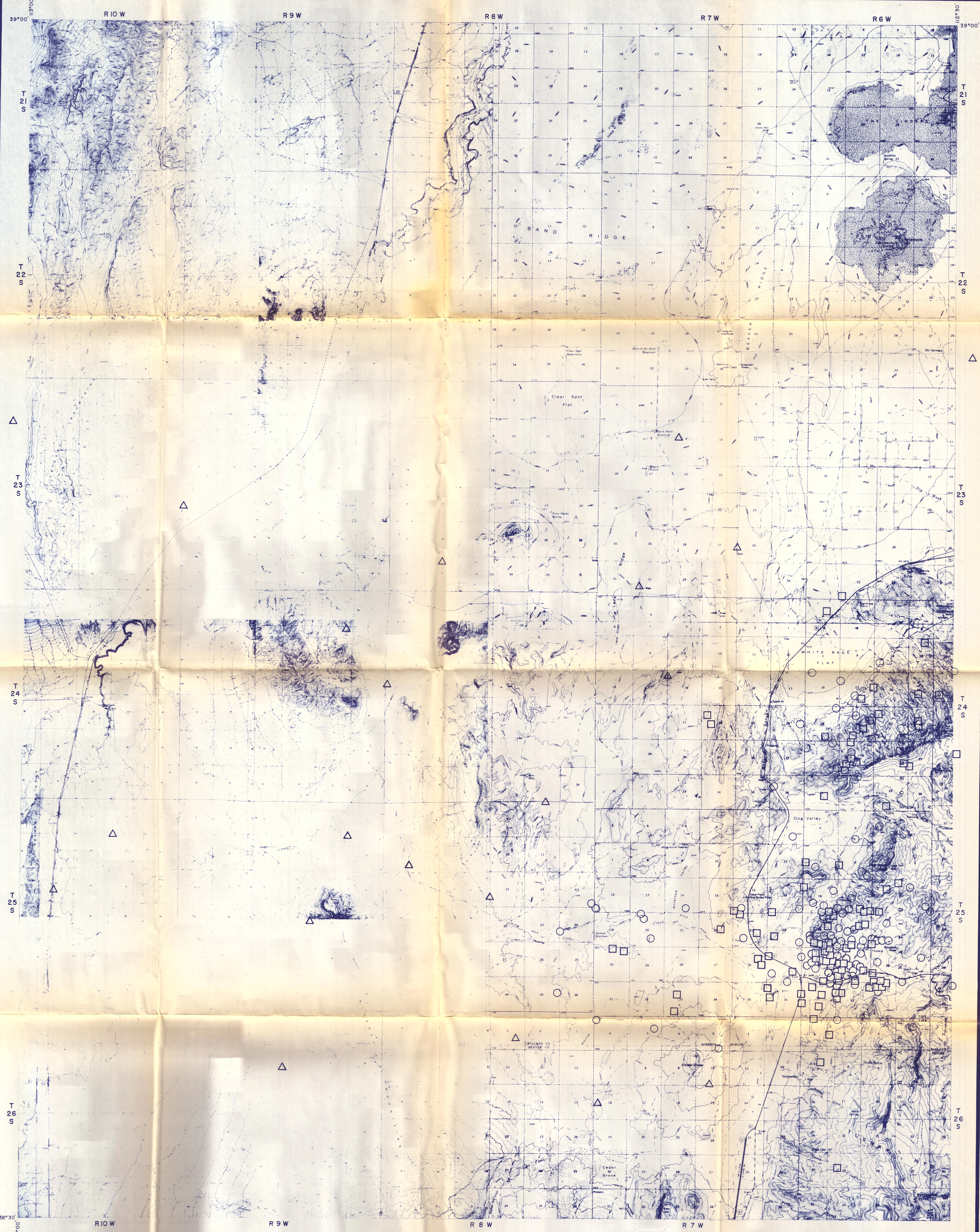


PLATE 5

COVE FORT - SULPHURDALE KGRA
&
ROOSEVELT HOT SPRING KGRA
(N. HALF)
UTAH

LEGEND

○ DATES OF ACQUISITION: DEC. 3-19, 1975

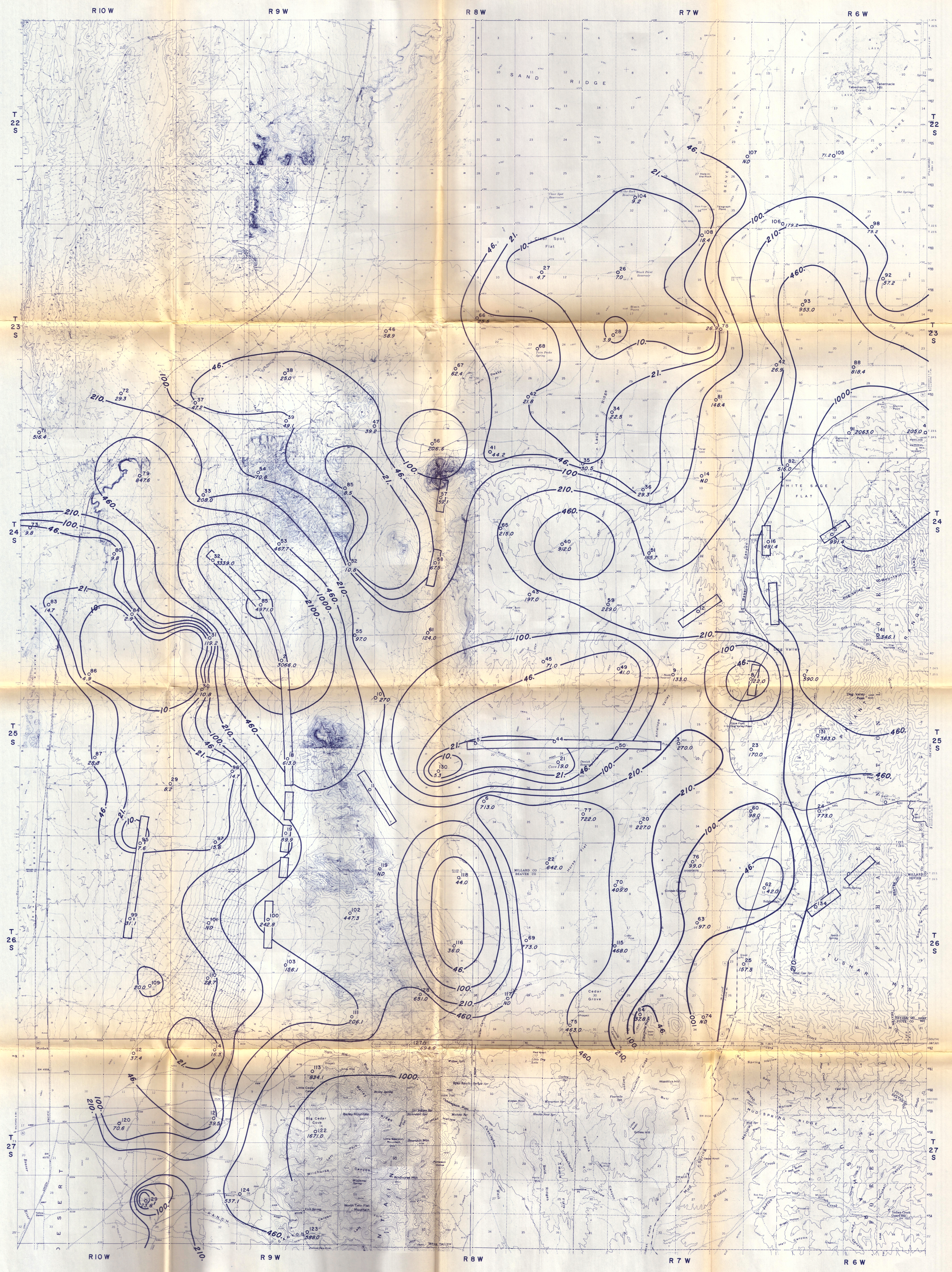
□ DATES OF ACQUISITION: MAR. 20-APRIL 9, 1976

△ MICROEARTHQUAKES
(ROOSEVELT-HOT SPRINGS TO COVE FORT)

EARTH POWER GROUP
TULSA, OKLAHOMA

HYPOCENTER LOCATION MAP
SURVEY BY SENTURION SCIENCES

SCALE: 1" = 1 MILE
DATE: 1976



COVE FORT-SULPHURDALE KGRA
&
ROOSEVELT HOT SPRING KGRA

UTAH

STATION NUMBERS 75
197.0 Pa

FAULT

PLATE 6

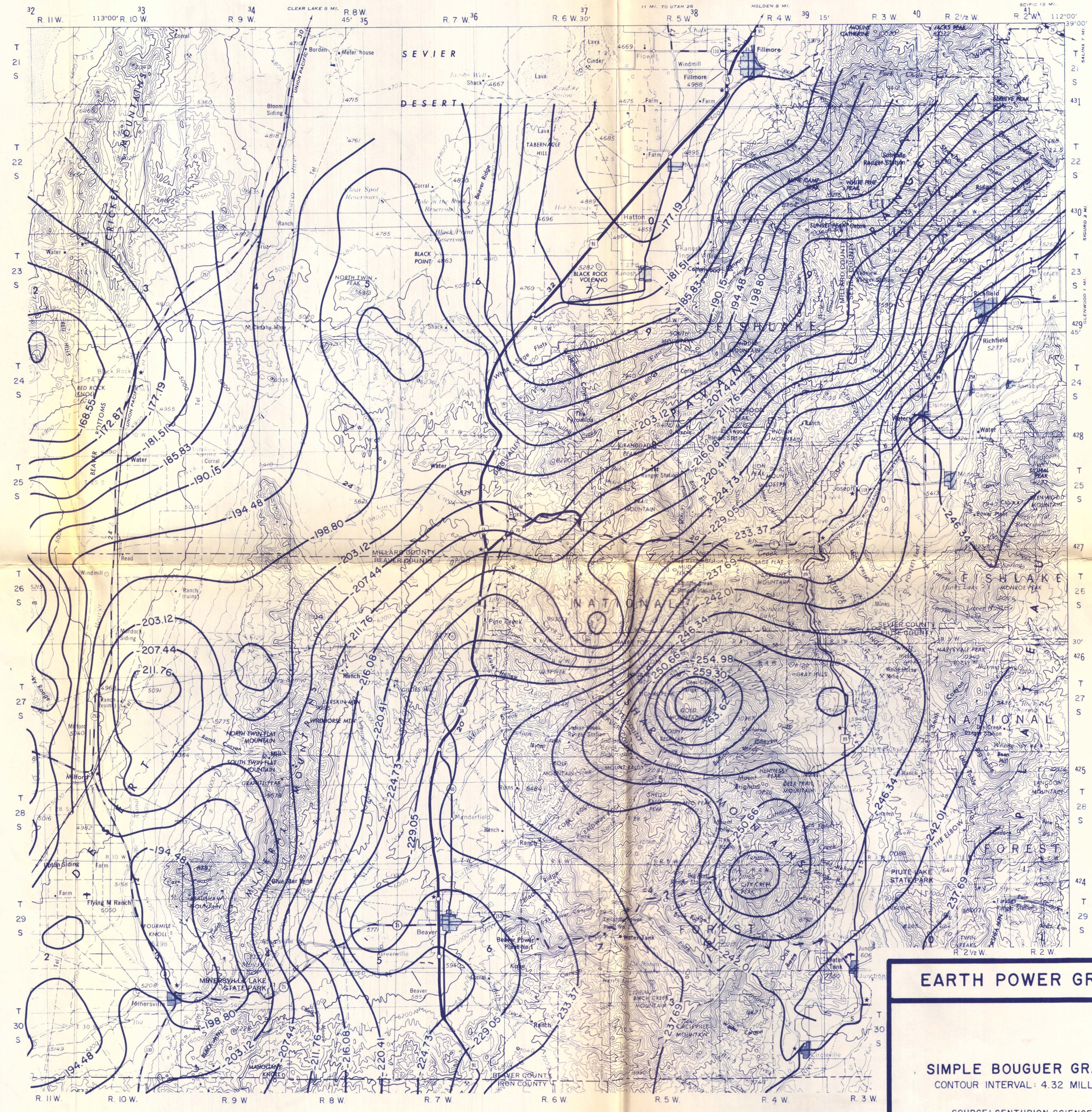
EARTH POWER GROUP
TULSA, OKLAHOMA

MAGNETOTELLURIC SURVEY

APPARENT RESISTIVITY
AT 100 SECOND PERIOD

CONTOUR INTERVALS
2.1, 4.6, 10., 21., 46., 100., 210., 460., 1000. & 2100.

SCALE: 1" = 1MILE DATE: FEBRUARY, 1976



EARTH POWER GROUP

SIMPLE BOUGUER GRAVITY
CONTOUR INTERVAL: 4.32 MILLIGALS

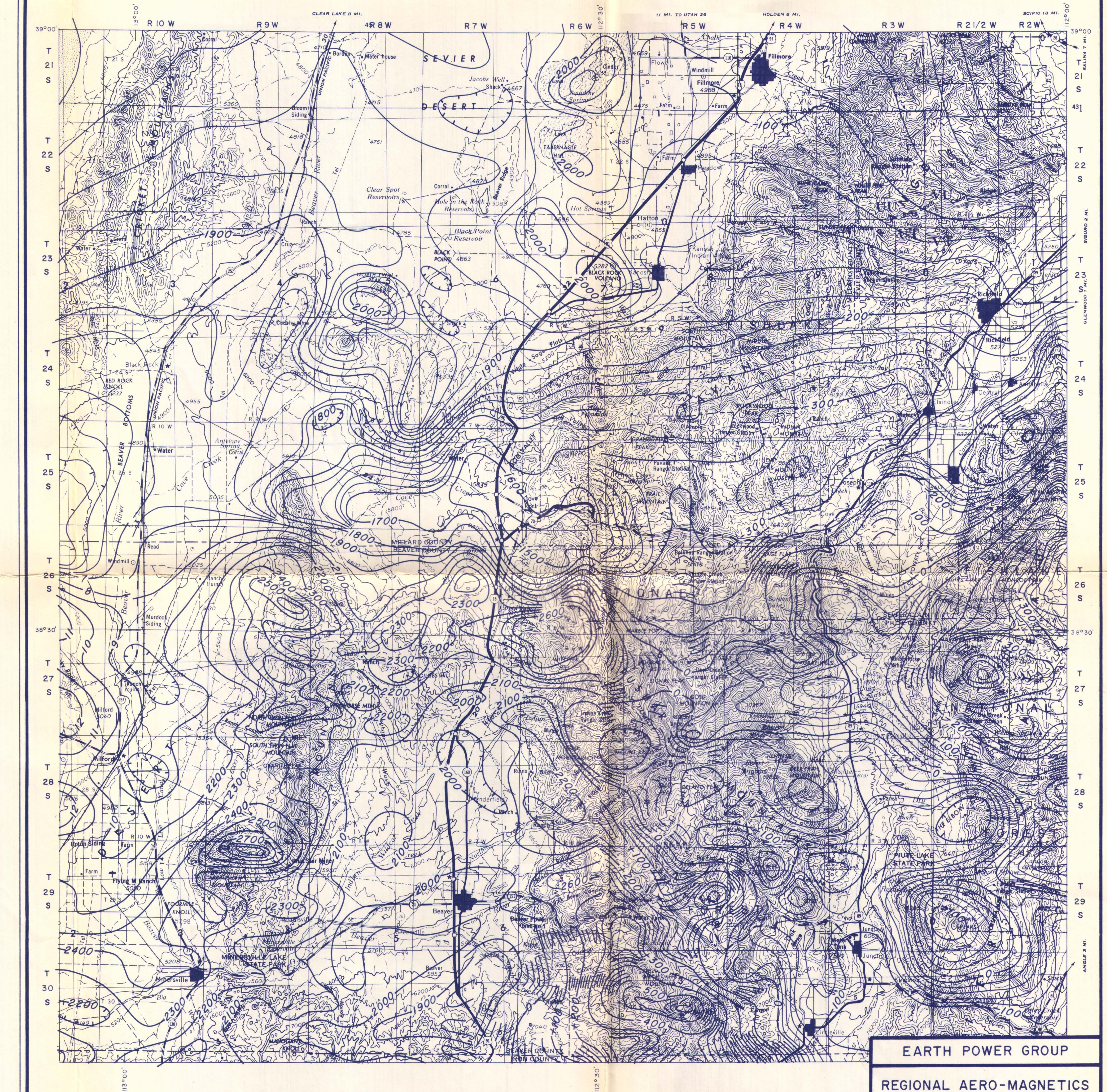
SOURCE: SENTURION SCIENCES

SCALE: 1:250,000

0 5 10

DATE: BY:

PLATE 7

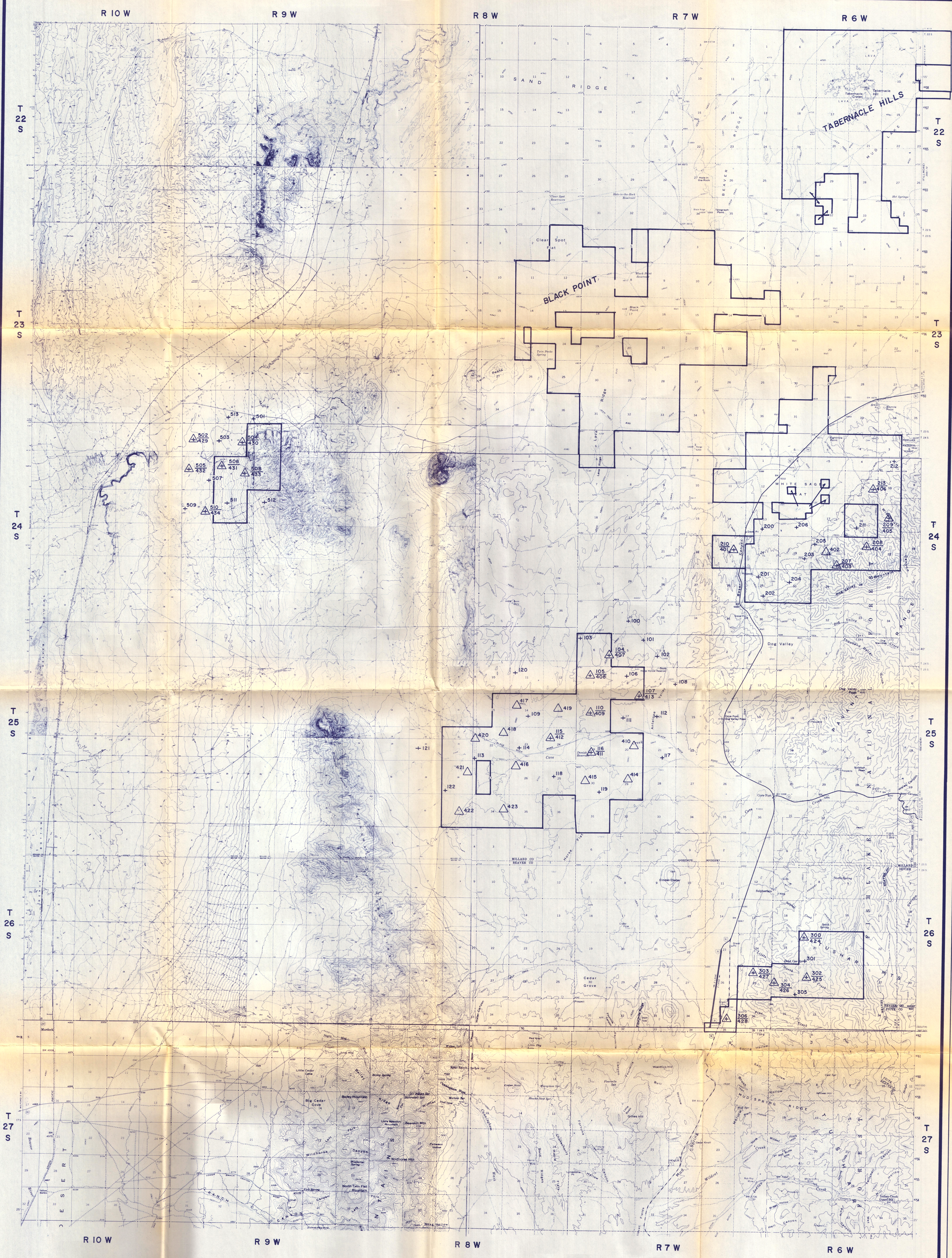


EARTH POWER GROUP

REGIONAL AERO-MAGNETICS
MILLARD & BEAVER COS., UTAH

SCALE

PLATE 8



RECOMMENDED LOCATIONS FOR
SHALLOW & INTERMEDIATE DEPTH
TEMPERATURE GRADIENT HOLES

LEGEND

+ = 300 FT. HOLE

△ = 1500 FT. HOLE

107
413