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FINAL REPORT

Remote Sensing and Geophysical Studies
Demonstrate the Indian Wells Valley and
Rose Valley are Open Basins, Kern, Inyo,
and San Bernardino Counties, California

Prepared For

EASTERN KERN COUNTY RESOURCE CONSERVATION DISTRICT

Prepared By

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Remote Sensing and Geophysical Studies Demonstrate that Indian Wells Valley and Rose Valley are Open Basins, Kern, Inyo, and San Bernardino Counties, California.

Introduction:

This report will serve as my final report for work started in 1986. Instead of rehashing the previously presented interim reports, this report will bring the structural and stratigraphic knowledge up to date. This report was delayed because of additional geophysical and remote sensing work in progress from 1988 to the present. Specifically, the work was delayed until the following reports were completed:

- 1) Review of the Geohydrology of the Indian Wells Valley Region, Kern, Inyo, and San Bernardino Counties, California.

Prepared by M. C. Erskine Phd

June 29, 1989

- 2) A Water Geochemistry Study of Indian Wells Valley, Inyo and Kern Counties, California
Volumes I and II NWCTP 7019

Prepared by J. A. Whelan Phd, R. Baskin, and A. M. Katzenstein

September, 1989

- 3) Tectonic Setting of the Coso geothermal Reservoir

M. C. Erskine Phd

Abstract published in AAPG Bulletin 74/15, May, 1990

and paper published in Coso Field Trip Guidebook AAPG

June 2, 1990

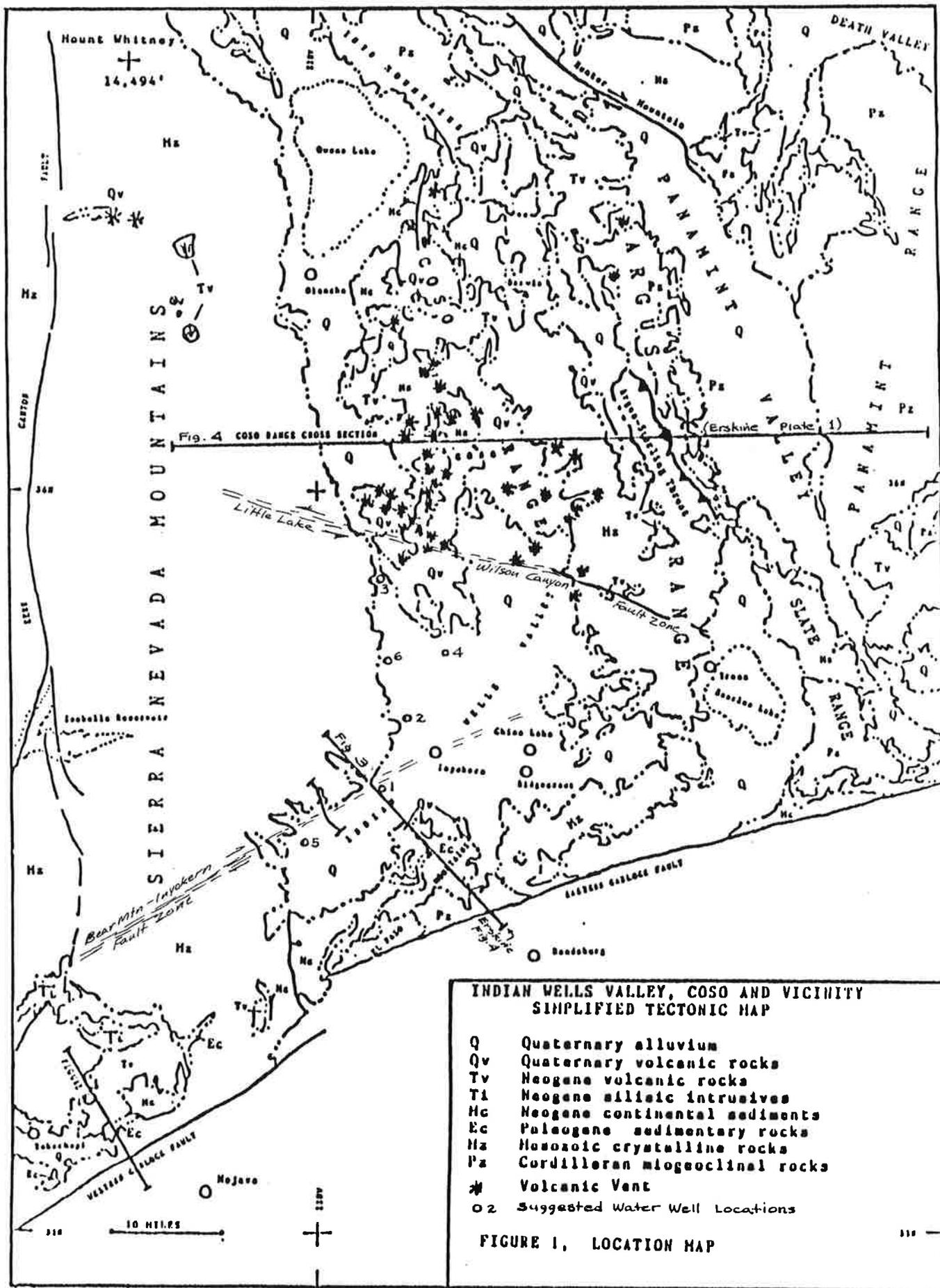
- 4) Structural Investigations at the Coso Geothermal Area Using Remote Sensing Information, Inyo County, California

W. H. Austin, 1990

Abstract published in AAPG Bulletin 74/15, May, 1990

and Abstract published in Coso Field Trip Guidebook AAPG

June 2, 1990



Prior to and during the time that W. Austin, D. O' Brien, C. Austin, and J. Moore were proposing the overthrust interpretation of the Southern Sierra Nevada Mountains two oil companies, Prairie Eagle and Hunt Oil Company, were doing proprietary seismic studies which have conclusively proved the overthrust interpretation of the Sierra Nevada Mountain front. In 1987 and 1988 the California Institute of Technology (Cal. Tech) published papers indicating a large volume of low velocity sediments at depths of 3 km to 5 km (9,843 feet to 16,405 feet) from the east side of Indian Wells Valley to at least as far west as Lake Isabella. (Figs. 8a & 8b, Ho-Liu et al 1988, Fig. 2, Page 4 this report) The only logical interpretation is that these low velocity sediments are the Paleozoic of the Cordilleran Miogeocline. It is expected that a significant amount of these sediments may be limestones seen in the El Paso Range to the south and under the Argus Thrust on the west side of Panamint Valley. The California Institute of Technology reports support 60 km (35 miles) of the overthrusting. Also of significance is the fact that the Cal Tech. data fails to show any evidence of the traditional eastern front of the Sierra Nevada Mountains, thus suggesting that the western edge of Indian Wells valley continues a significant distance westward under the overthrust Sierra Nevada Mountains.

As stated previously, the importance of the overthrust interpretation is that it explains the enormous Sierran water flow into the Coso Geothermal Area, 46,400 acre feet per year currently, and suggests even larger flow into the deep western edge of Indian Wells Valley.

The recommendations in this report back the Erskine/Lofgren concerns that up to now water level measurements have been inaccurate and unsystematic. Measuring water levels without having accurate well elevations and without measuring systematically for several years at the same time during both the irrigation and non irrigation season is a waste of time and money.

A Curie Isotherm Study is recommended to show the extent to which Indian Wells Valley is influenced by the possible major geothermal prospect centered 3 km. west of the NWC Airport as interpreted by the Cal. Tech. reports. (Cost to cover a 60 x 25 mile area would be \$110,000)

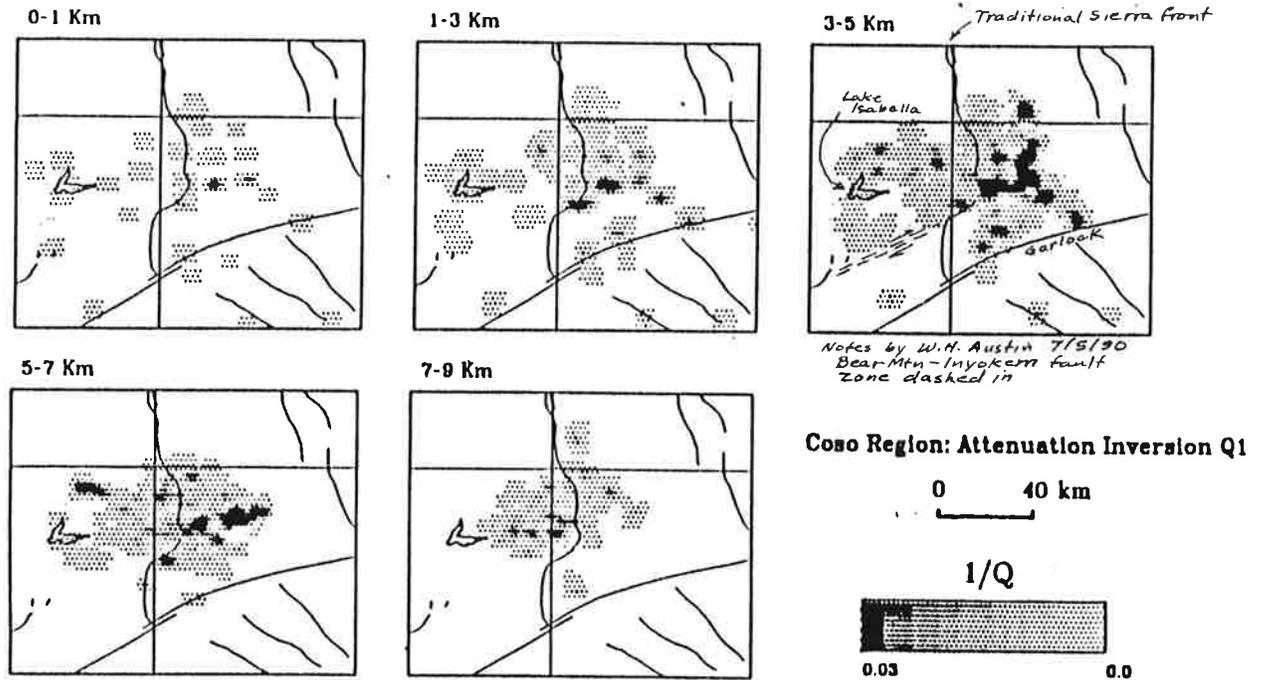


Fig. 8a. Results of attenuation inversion using the Coso velocity model shown in Figure 2a. Depth slices at (1) 1-3 km, (2) 3-5 km, (3) 5-7 km, and (4) 7-9 km are shown. A value of 1 was used for $k_1 k_2$. Attenuation anomalies are resolved beneath the Coso Range and the Indian Wells Valley in the depth range of 3-5 km. The locations of these two anomalies agree very well with the low-velocity anomalies obtained by inversion of P wave travel times [Walck and Clayton, 1987]. The anomalies at the edge of ray coverage (see Figure 8c) are probably spurious resulting from low hit counts or poor azimuthal ray coverage. The Coso range anomaly disappears below 5 km, but the Indian Wells Valley anomaly still exists at 5-7 km depth range.

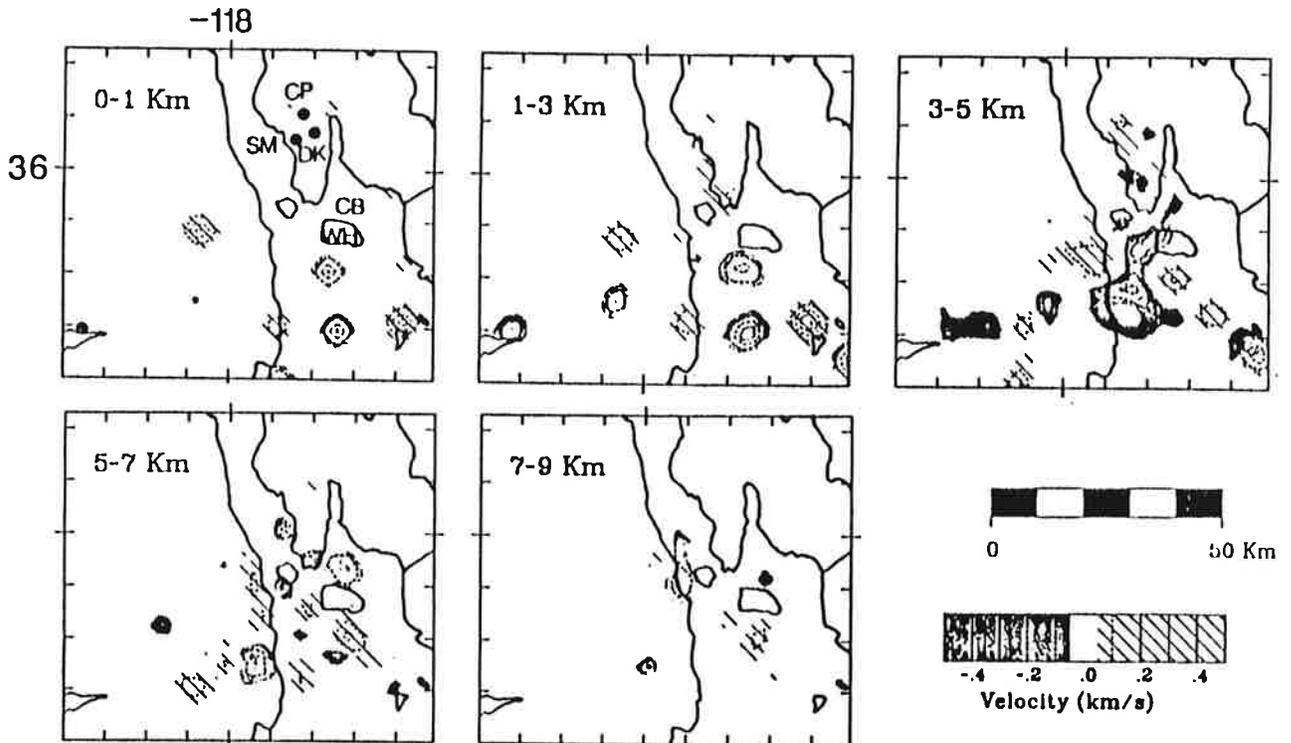


Fig. 8b. Results of travel time tomography [Walck and Clayton, 1987] for the same depth slices as in Figure 8a. The area covered by their study (80 km x 70 km) is smaller than the area covered by this attenuation study (144 km x 144 km). CP stands for Cactus Peak, SM for Sugarloaf Mountain, CB for Coso Basin, DK for Devil's Kitchen, and WH for White Hills. Shaded regions indicate slow anomalies while hatched areas are fast. Notice the good agreement in locations of these two anomalies (Coso Range and Indian Wells Valley anomalies) in the depth slice of 3-5 km with the anomalies resolved by attenuation inversion shown in Figure 8a.

Figure 2

A minimum of two and possibly three vibroseis lines are recommended as in previous reports. All of one and a portion of another may be available for purchase. The savings by purchasing already shot lines are unknown. Shooting the three recommended lines from scratch would be \$393,000.

Erskine/Austin recommended 4 deep water well tests in the Erskine June 29, 1989 report. In this report two other possible locations are suggested. Loffland Drilling Company has several rigs stacked at Coso and probably could offer a good price for deep water well tests. An 8,000 foot test may cost up to \$700,000 depending on the amount of casing run.

Structure and Stratigraphy of Indian Wells Valley and Rose Valley

In 1986 the Eastern Kern County Resource Conservation District requested a fault/fracture study of Indian Wells Valley and adjacent areas to try to better understand the geologic structure and its relation to ground water flow into and under Indian Wells Valley. There has for some time been an argument about ^{whether} Indian Wells Valley was open or closed. If closed there might be only a limited ground water resource which would support only limited development of the Valley and which might have to be closely monitored and managed to even support the existing population and activities. If however, the Valley was open there might be significant amount of water flowing into and under the Valley which might give a brighter future for the current development and activities and possibly a bright future for additional development.

With this in mind 12 Orthophotos of the Indian Wells Valley/Rose Valley and adjacent areas were annotated to outline the fault/fracture pattern and look for surface patterns which might be related to buried structures which might affect both shallow and deep ground water flow. (W. Austin, 1987c) Detailed Orthophoto work along the Sierra Nevada Mountain/Indian Wells Valley contact soon made it obvious that the traditional tilted block fault interpretation of the Sierra Nevada batholithic granites was not supported by annotation and interpretation. The irregular edge of the Eastern Sierra Nevada Mountains showed this supposed normal faulted front to be segmented by many recent NW-SE faults which were left-lateral with the north side moving NW. Major landsliding activity was visible on the Orthophotos and indeed can easily be seen on the ground west of Little Lake where the Sierras are offset over one mile on the Wilson Canyon-Little Lake Fault Zone which from the air and on satellite imagery cuts across the Sierra Nevada Mountains to the San Joaquin Valley. This important recent fault zone crosses the East Fork of the Kern River and in dry years the entire flow of the East Fork of the Kern north of the fault disappears into this fault zone

From the mouth of Indian Wells Canyon to the mouth of Bird Spring Canyon the Sierran granites are offset by a right lateral fault zone at least 14.3 miles. This offset appears to be controlled by a fault zone that runs along the northwest face of Bear Mountain, southeast of Bakersfield, northeastward through Caliente passing just north of Mayan Peak across the mouths of Horse Canyon/Sage Canyon passing just north of Freeman Junction heading toward Inyokern. This zone is plainly visible on the 1:250,000 scale FCC satellite image and is equally visible on the 1:250,000 scale plastic relief maps of Bakersfield and Trona. While working on the Freeman Junction Orthophoto at the mouth of Cow Haven Canyon it was found that elliptical curvilinear patterns suggested buried anticlines which had either been sheared off or over ridden by the Sierran granites on the north side of the apparent right lateral Bear Mountain/Freeman Junction Fault zone. It was at that point that a sketch overthrust cross section interpretation of the Sierras was presented at a meeting of the EKCRC in December 1986. Needless to say, this interpretation, which was such a radical departure from the 1874 views of Gilbert of the USGS, created a firestorm of criticism from some local Indian Wells Valley geologists.

Unknown at that time was the fact that two oil companies were already working on a Sierra Nevada Mountain overthrust interpretation and had already done reflection seismic work which they believed proved the Sierra Nevada overthrust concept. Hunt Oil Company was one of the companies which did extensive leasing in Southern Indian Wells Valley with the idea of drilling an oil and gas test between Walker Pass and Freeman Junction. This test was expected to spud in granite and drill into sediments in a structure below the overthrust granite. Figure 4 of Erskine's 1989 report to the EKCRC (Fig. 3, Page 9 of this report) indicates that a well drilled at Freeman Junction would probably find the section shown on the following page:

Possible Freeman Junction Section

Miocene Ricardo Formation	-----	Near surface to 1,260 feet
Unconformity	-----	1,260 feet
Sierra Nevada Mesozoic Crystalline Rocks, granites etc.	--	1,260 feet to 4,120 feet
Thrust Plane	-----	4,120 feet
Paleocene & Eocene Goler Formation	-----	4,120 feet to 11,000 feet
Disconformity	-----	-11,000 feet
Sedimentary rocks of the Cordilleran Miogeocline		
Including Paleozoic limestones	-----	11,000 feet to 15,500 feet?

W. Austin has personally examined a Prairie Eagle seismic record section in from Cow Heaven Canyon Southeast to the El Paso Mountains which fully confirms Figure 4 of the Erskine 1989 report to the EKCRCD. (Fig. 3, Page 9 this report) (O' Brien, Puckett, Seibert and W. Austin, March 3, 1989). It should be noted that the Cow Heaven Canyon seismic record section was fully consistent with the report entitled Compilation and Interpretation of Gravity and Magnetic Data in the Indian Wells Valley Area, including portions of Bakersfield and Trona 1:250,000 Quadrangles, California, (O' Brien 1988).

From mid 1988 to the present W. Austin has worked on remote sensing studies in the Coso Geothermal Field and surrounding areas for the California Energy Company. This work has included very detailed Linear Fault/Fracture Studies and Curvilinear Studies on Orthophotos, as well as detailed studies on 1:6000 scale B & W film positives. Very detailed studies have also been done on a 1:100,000 scale FCC satellite image of the Coso Range. These studies fully support the 1986 overthrust interpretation of the Sierra Nevada Mountains and also support of overthrust interpretations of the O' Brien 1988 report to the EKCECD concerning the Sierra Nevada Mountain and Argus Range thrusting.

In 1989 Erskine submitted a report to the EKCRCD entitled Review of the Geohydrology of the Indian Wells Valley Region Kern, Inyo, and San Bernardino Counties, California. Erskine has spent a great deal of time over the last several years doing both research and field work on the tectonics of the Sierra Nevada mountain front, Rose Valley, Indian Wells Valley, the Argus Range, etc. and has published several cross sections depicting the structure based on surface and geophysical work. Erskine's Figure 4 and Plate 1 from his 1989 report to the

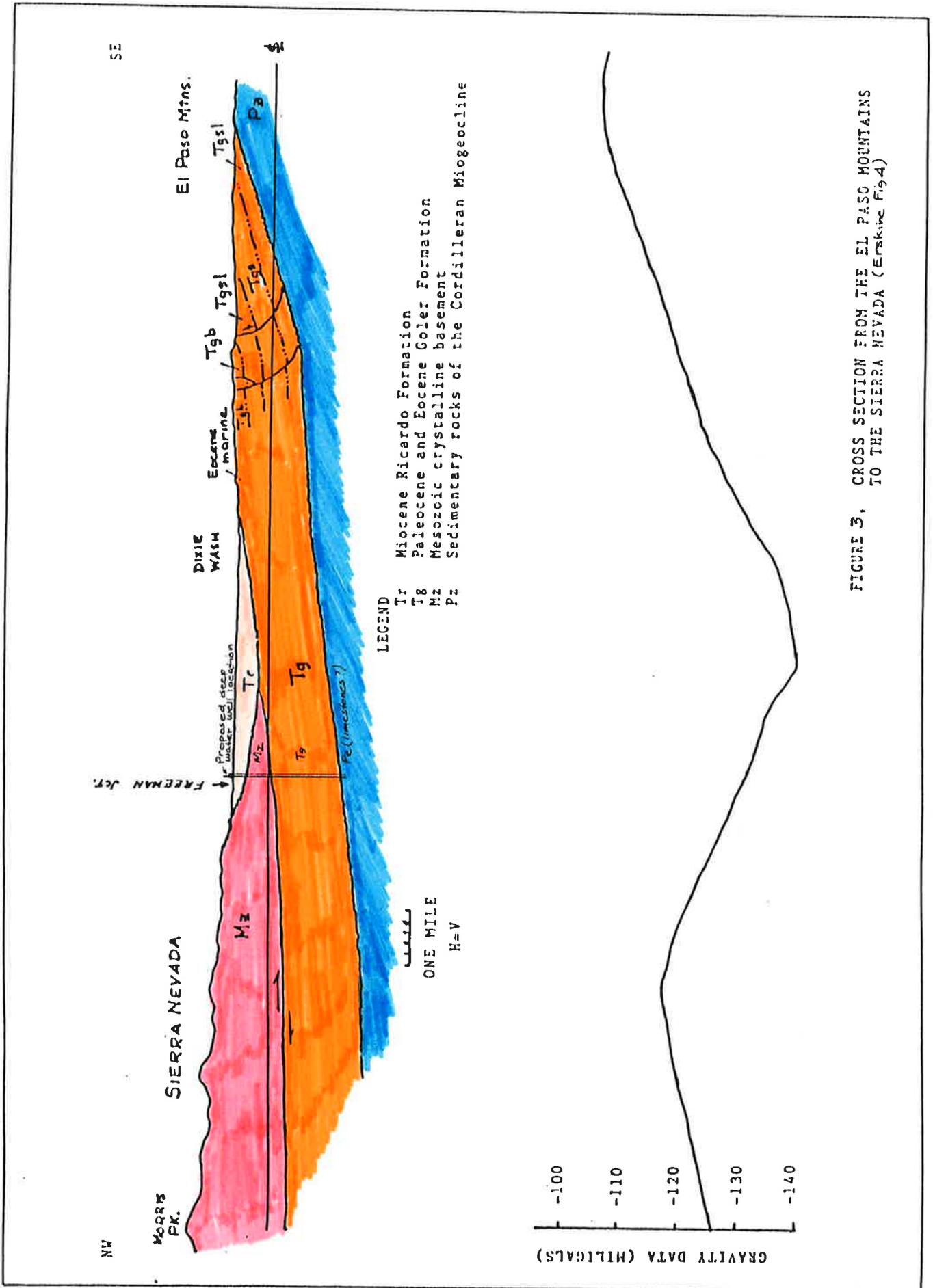


FIGURE 3. CROSS SECTION FROM THE EL PASO MOUNTAINS TO THE SIERRA NEVADA (Erskine Fig 4)

EKCRC D are reproduced as Figure 3 and Figures 4a, 4b, & 4c on Pages 9, 12, 13 & 14 of this report. In the recent American Association of Petroleum Geologists Annual Meeting in San Francisco both Erskine and W. Austin were invited to give papers on their work in the Coso Geothermal Area. Abstracts of both papers are attached in the Appendix A. It should be noted that W. Austin's 1:100,000 FCC satellite image annotations and interpretation supports Erskine's idea's that the Sierra Nevada Mountains have slumped significantly following the last period of overthrusting.

Sequence of Events as Shown on Erskine Plate 1.

(Figs. 4a, 4b, & 4c, Pages 12, 13, & 14 this rept.)

- 1) Eastward Sierran overthrusting, Coso Range anticline formation and overthrusting and Argus Range thrusting on low angle 15° thrust planes in the Mesozoic.
- 2) After compression ends the Sierra Nevada Mountains slide westward on the old thrust planes, the Coso Range slides westward but at a lesser rate than the Sierra Nevada Mountains.
- 3) The Sierra front slumps eastward toward Rose Valley whereas the surface detachment block of the Coso Range slides westward toward Rose Valley and eastward into Coso Wash. The basalt covered west flank of the Argus Range slumps westward into Coso Wash. All of the slumps give a surface expression of extension but at depth the features are all related to compression. Similar features have been found associated with the so called "Block Faulted Mountains" of Nevada. (Erskine personal communication 1989) An EW and NS vibroseis line at Coso controls the interpretation of Erskine's Plate 1 and extensive confidential oil company seismic lines in Nevada control the new collapsed overthrust interpretation of the Nevada Mountains. (Refer to Fig. 8, Pg 26) Note on Erskine's Plate 1 (Figure 4a, 4b, & 4c, Pages 12, 13, & 14 this report) that a well on the east side of Rose Valley would probably drill the following approximate section:

Possible Section East Side Rose Valley

Quaternary Alluvium - - - - - Surface to 800 feet?
Plio-Miocene Coso Formation - - - - 800 feet? to 3,000 feet
Unconformity - - - - - 3,000 feet
Mafic intrusive and Coso - - - - -3,000 feet to 6,000 feet
Range thrustplate granites
Listric Slump Block Fault- - - - - 6,000 feet
Sierran granites in slump - - - - -6,000 feet to 9,500 feet
Thrust Fault - - - - -14,000 feet
Paleozoic sediments including thick?
limestones may be metamorphosed
or under going metamorhism. - - -14,000 feet to 18,500 feet?

The Argus Range granites are thrust over isoclinally folded Paleozoic limestones on the west side of Panamint Valley (Erskine's Plate 1) and the Miocene Goler Formation is deposited disconformably on the Paleozoics of the east side of the Argus Range. It is very probable then that even though there is no Paleozoic exposed on the east side of the Indian Wells Valley, there may be Paleozoic rocks under a significant portion of the Indian Wells Valley. On the west side of Indian Wells Valley near Brown Road and Highway 395 it seems likely that the section might be similar to that proposed for a well at Freeman Junction. If no granite was encountered under the pediment, the test might drill 6,000 to 7,000 feet of Plio-Miocene sediments and then go into Paleozoic limestones. Even if a test went into granite at 7,000 feet it would be expected to cross a thrust and go back onto Paleozoic limestones after probably drilling no more than 2,500 feet of Argus granite thrust slice. These projections are of major importance concerning deep water possibilities in Indian Wells Valley and point up the importance of the proposed seismic E-W Line 3 starting in Sand Canyon and crossing Indian Wells Valley to the Argus Range. Will the western side of Indian Wells Valley look like Figure 4 of Erskine (Figure 3, Page 9 of this report)? If the deep well intersects highly fractured Sierran granite the water flow rate might be similar to wells at the Coso Geothermal Field where 46,400 acre feet of water per year are currently being produced from fractured granite in a 5 square mile area. Large flow rates of water might also be found in cavernous Paleozoic limestones expected to be found under the Plio-Miocene Coso/Goler Formation. Water wells which stay in the Plio-Miocene may not have

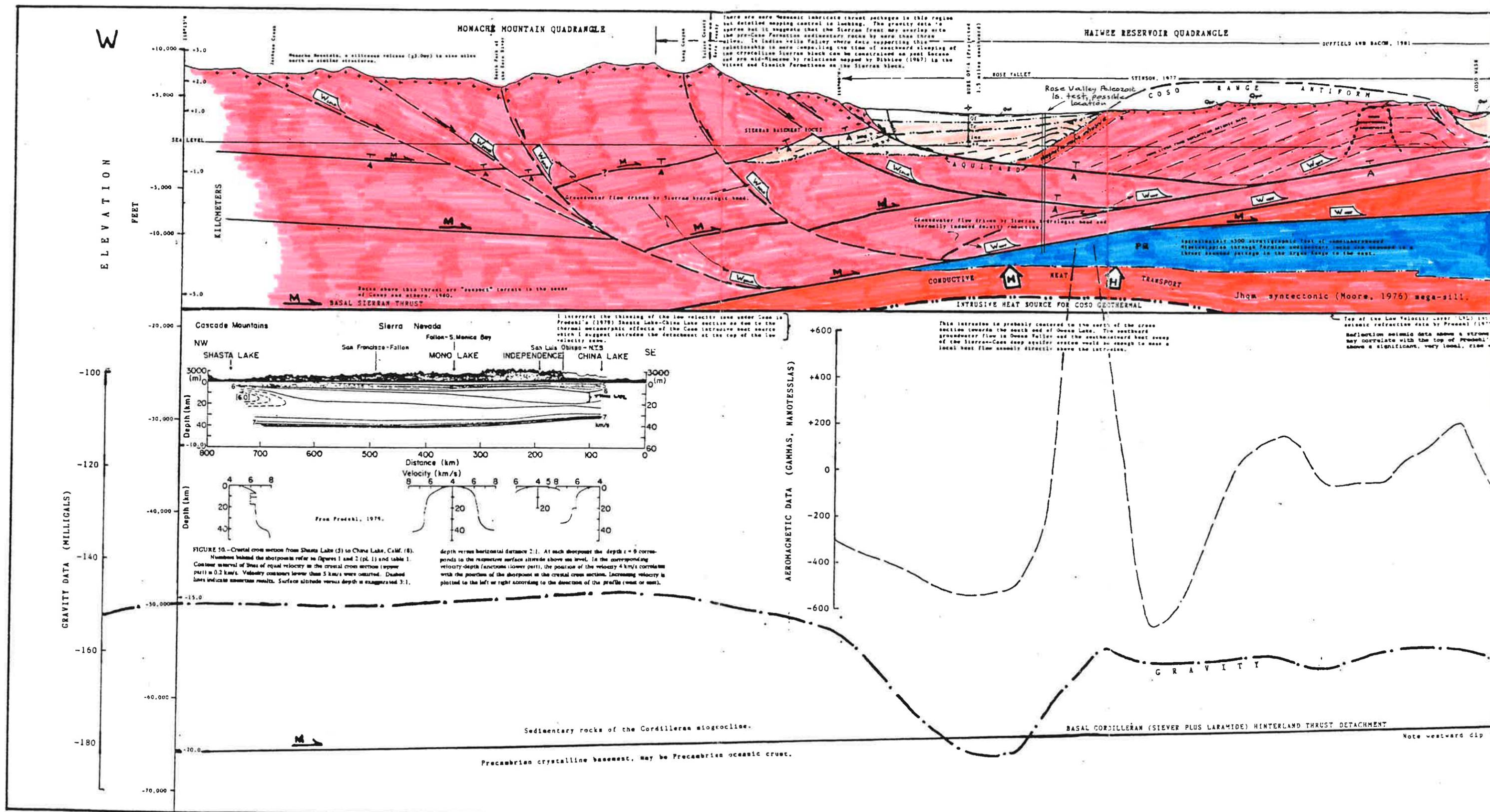


Figure 4a

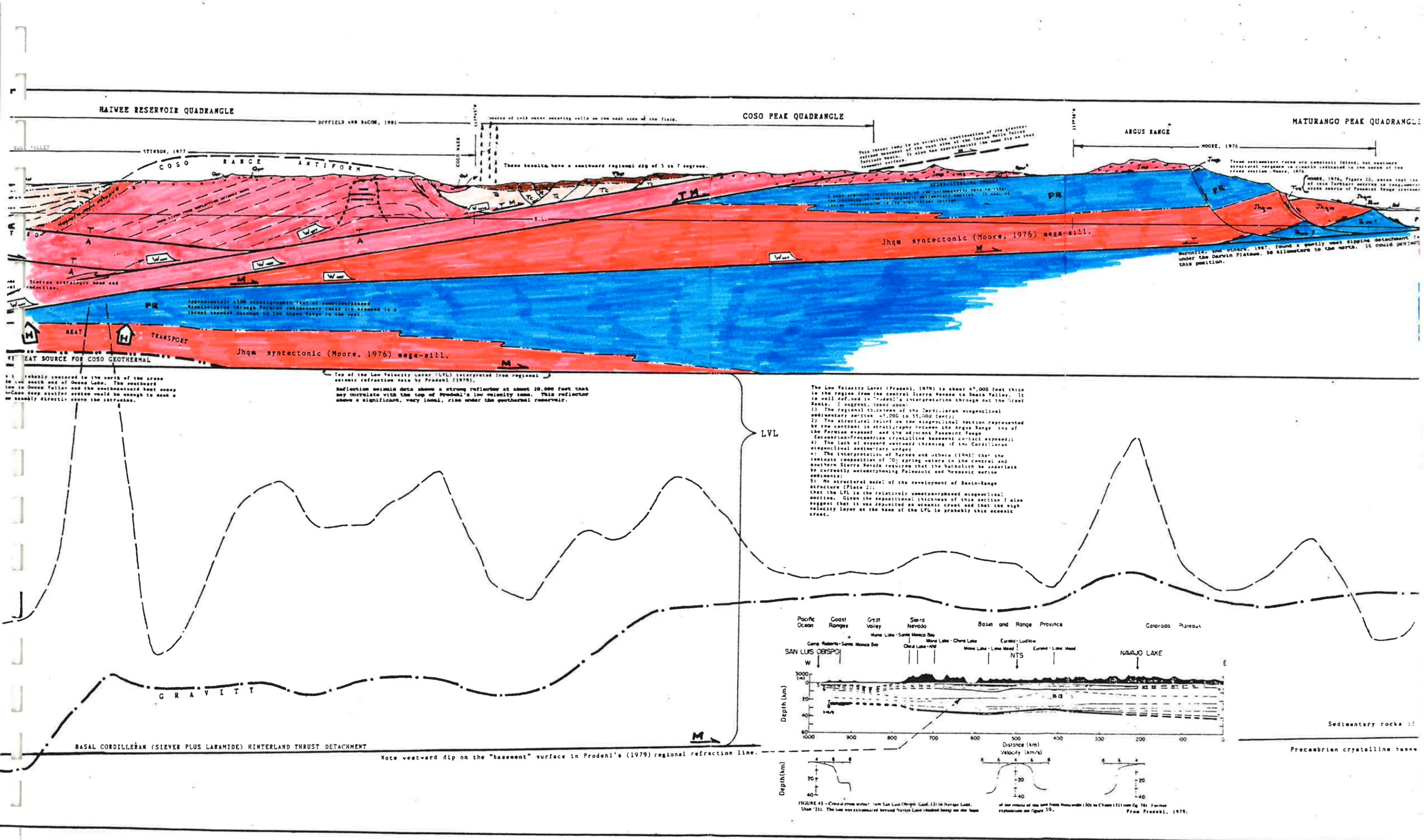


Figure 4b

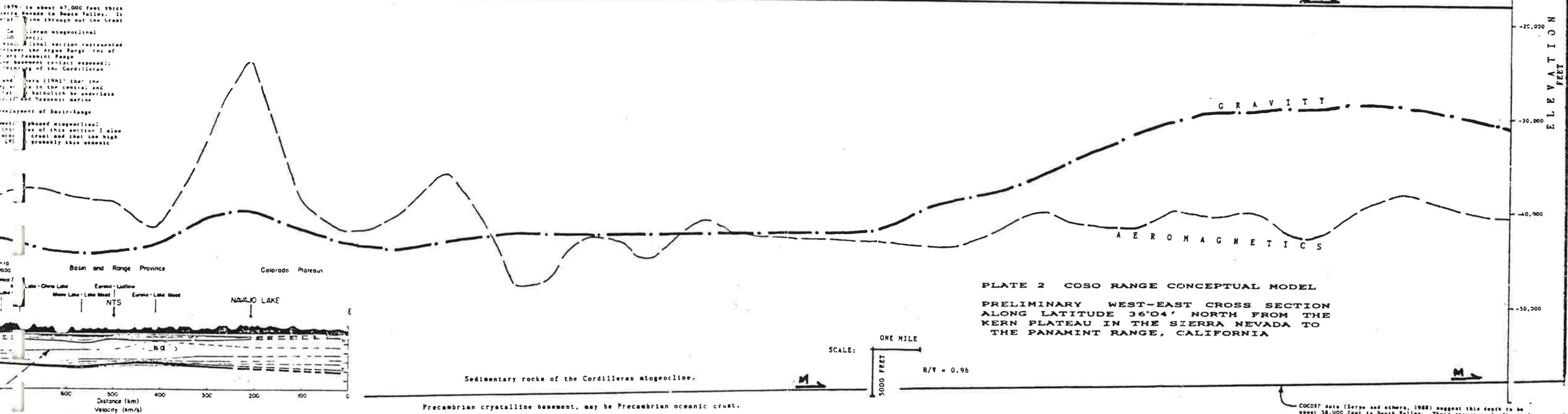
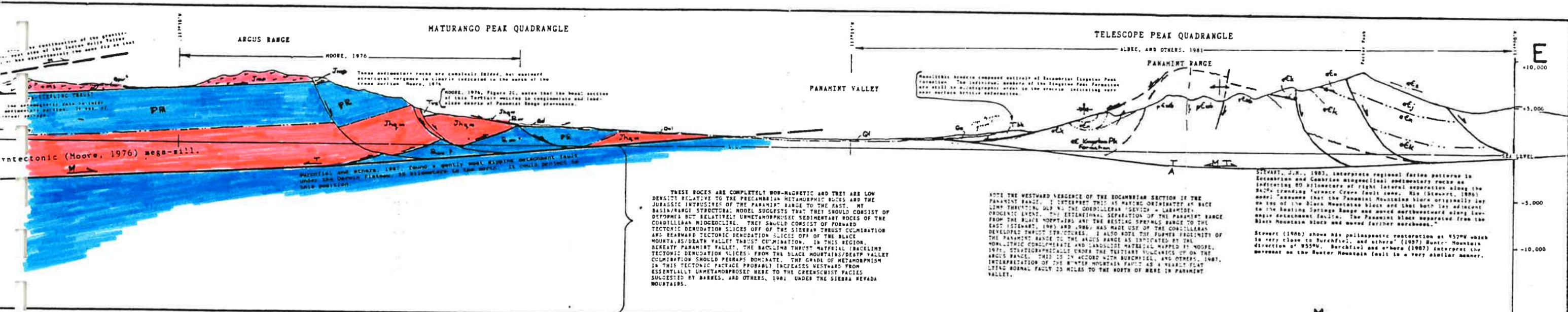


PLATE 2 COSO RANGE CONCEPTUAL MODEL
 PRELIMINARY WEST-EAST CROSS SECTION
 ALONG LATITUDE 36°04' NORTH FROM THE
 KERN PLATEAU IN THE SIERRA NEVADA TO
 THE PANAMINT RANGE, CALIFORNIA

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COCORP data (Serra and others, 1988) suggest this depth to be about 58,000 feet in Death Valley. Their structure (reflector) "C" which they interpret as a fault and I here interpret as a thrust fault ramp developed in the Cordilleran orogenic event that has been reactivated as a normal fault by late Tertiary and Quaternary extensional tectonics off from the basal detachment in Death Valley, 10 miles east of the east end of this cross section. The ramp (reflector "C" of Serra and others, 1988) strikes N30E and dips about 35° to the west. However this orientation is rather crude because of uncorrected near surface velocity effects.

Figure 4c

as high a potential as wells which produce from fractured granite or cavernous Paleozoic limestones. However, it should be noted that on that one of the Mead wells near Brown Road routinely pumps 1,600 gallons per minute from an 800 foot well. The standing water level in this well is 236 feet and drawdown when pumping 1,600 gpm is down to 247 feet. It was found during testing that pumping was limited by the horsepower of the pump. The maximum this well could pump was 4,700 gpm with a draw down to 249 feet. (See Appendix 2 Hydraulic Conductivity of Selected Rocks).

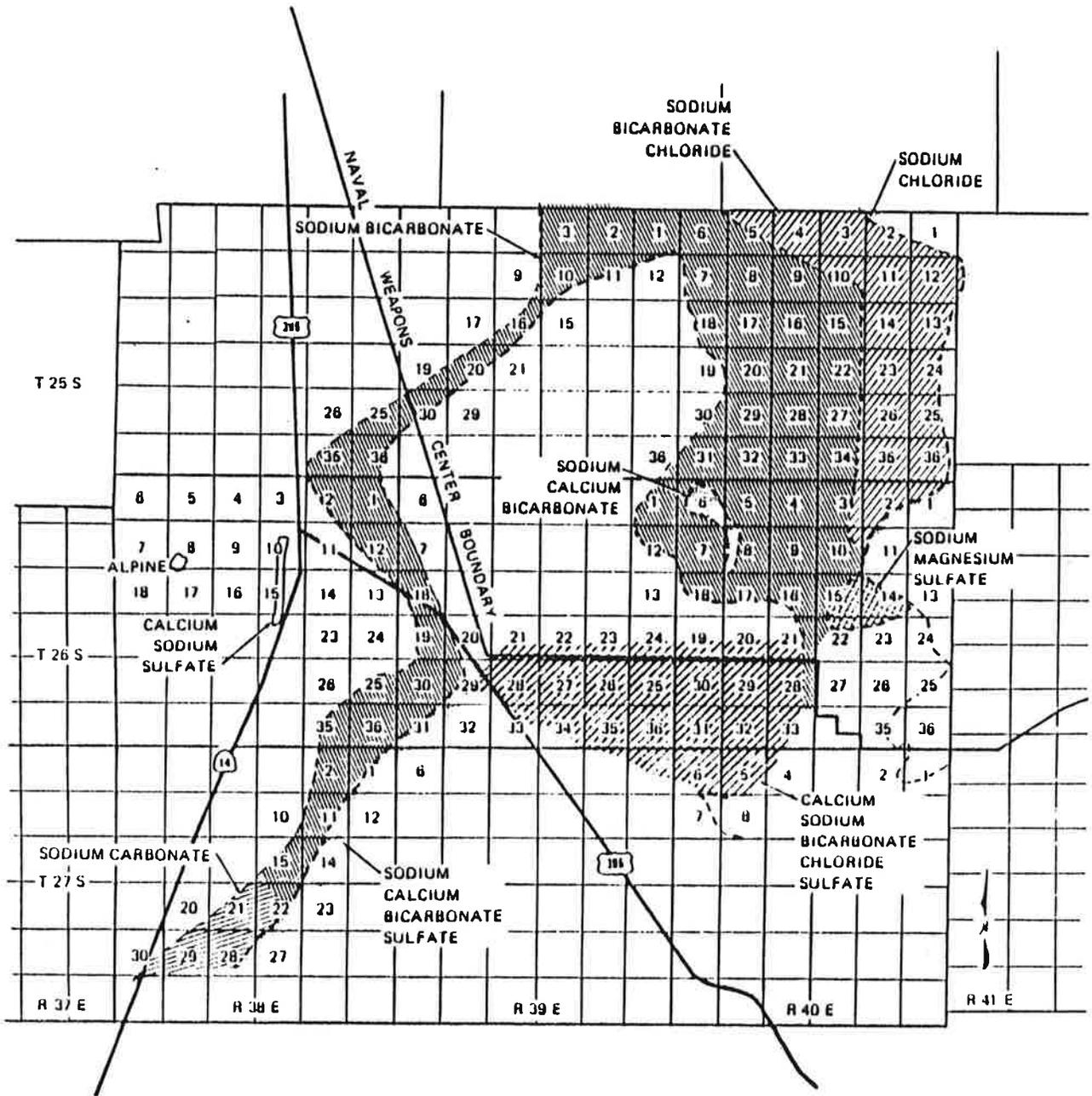
The paper published by the Seismological Laboratory, California Institute of Technology, Pasadena, California, by Walck and Clayton 1987 utilized some 429 local earthquakes to make some calculations concerning the structure and Stratigraphy of the Coso Area. Ho-Liu et al, 1988 California Institute of Technology used a different approach but came up with similar conclusions. Ho-Liu et al Fig. 8a & 8b are listed as Fig. 2 on page 4 of this report. Three interesting conclusions can be made about findings of these two papers.

- 1) Although drawn on all their maps there is no seismic evidence for the Sierra Nevada Mountain eastern edge in their data.
- 2) A major geophysical anomaly, probably related to a deep geothermal heat source, is indicated centered 12 km (7.5 miles) east of the Sierra Nevada Mountains or 3 km (1.8 miles) west of China Lake Naval Weapons Center Airport.
- 3) Low seismic velocities indicate a large volume of sediments at 3 km (9,840 feet) to 5 km (16,400 feet) extending from the east side of Indian Wells Valley to at least as far west as Lake Isabella. In view of the presence of carbonate springs in the High Sierra West of Indian Wells Valley (Barnes and others 1981) it seems likely that the low velocity sediments under the Sierran granites may be sediments of the Cordilleran Miogeodine which includes thick limestones. These low velocity sediments go right through the classic block faulted east edge of the Sierra Nevada Mountains indicating the likelihood that the Sierran granites are probably sills, not a batholith, and are overthrust at least 60 km (37 miles) eastward over Paleozoic and Tertiary sediments.

The importance of the slumped overthrust interpretation is that it eliminates the closed basin concept of Indian Wells Valley and it opens the basin up to receiving enormous amounts of water from the Sierra Nevada Mountains. A five square mile area of fractured granite at Coso is capable of producing 46,400 acre feet of water per year through deep wells. The western edge of Indian Wells Valley could easily contain over eight Coso Areas placed end to end. If it is assumed, as seems likely, that deep well production from fractured granites under the west side of Indian Wells Valley might be similar to that from wells at Coso, it might be possible to produce over 370,000 acre feet of water per year from deep wells in a forty square mile area. Although logical on the basis of current experience at the Coso Geothermal Field, this will never be known until a series of deep water wells are drilled. (6,000 feet to 8,000 feet). A minimum of three vibroseis lines would guide the placement of deep tests and would help tie the results at the Coso Geothermal Field with Paleozoic outcrops in the El Paso Mountains and verify the Erskine Figure 4. (Figure 3, Page 9 of this report)

Dr. Whelan has just submitted to the Navy his report on the Isotope Geochemistry Study NWC TP 7019 Supplement of waters in the Sierra Nevada Mountains, Rose Valley, Coso Geothermal Area and Indian Wells Valley. This report appears to confirm the Sierra Nevada Mountain origin of most of the fluid being produced at the Coso Geothermal Field and appears to indicate the probability of Indian Wells Valley recharge from the Sierra Nevada Mountains. (Personal communications from Dr. Whelan 1990) It appears that a major conduit is the Wilson Canyon-Little Lake Fault Zone. Water appears to flow down that fault zone from the Sierra Nevada Mountains and flow NE onto the Coso Geothermal Field and probably runs south and southwest from the same zone into the deep portions of Indian Wells Valley. (See Appendix C)

An examination of Figure 3 Contd. of the Whelan 1989 Water Geochemistry report shows an inverted horseshoe pattern of sodium bicarbonate sulfate waters. (Figure 5, Page 17 of this report) It is suggested that this pattern represents the position of important NE-SW subsurface faults which bring deep subsurface water which is in contact with Paleozoic limestones up to mix with near surface water. The W. Austin 1987c Indian Wells Valley



c. Detail 2.

(Whelan 1989) FIGURE 3. (Contd.)

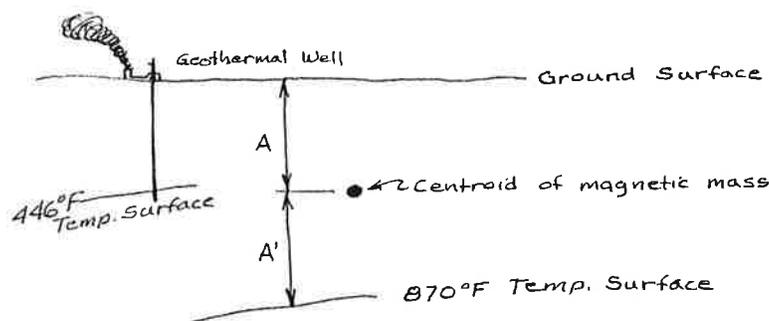
Figure 5

Photogeologic Fault/Fracture Study shows the close spaced Fault/Fracture pattern which may govern near surface water flow. The 4 deep well locations recommended by Erskine/Austin in the Erskine 1989 report to the EKCRCDC referred to this Fault/Fracture pattern as has W. Austin in the recommended 2 additional deep tests in this report. The important NE-SW Fault/Fracture trends which may feed water into the Coso Geothermal Field from the Wilson Canyon-Little Lake Fault Zone into the Geothermal Field are sketched on Figure 8, Page 32 of this report. Fractures related to water quality patterns in Indian Wells Valley as shown by Whelan 1989, Figure 5, Page 17 of this report and sketched on Figure 8 , this report.

Exploration and Evaluation Methods

The EKCRCDC should consider participating in a Curie Isotherm Study which would run from the South end of Owens Lake North of Rose Valley to the South end of Indian Wells Valley.

A Curie Isotherm Study is a magnetic geophysical survey which prepares a contour map on the 870° F isotherm surface. At the temperature of 870° F rocks lose most of their magnetism. The distance between the surface and the depth to this high temperature can give some idea as to the depth to the 446° F isotherm which is the temperature needed for geothermal plants like those at Coso.



Part of the reason for the large groundwater flow rates at Coso may be related to the thermal bulge under the Coso area. The survey area would be approximately 96 km by 40 km. (60 miles by 25 miles) It is suggested that this survey be a joint U.S. Navy, California Energy Company, EKCRCDC effort. The large apparent geothermal anomaly in Indian Wells Valley indicated by the California Institute of Technology Geophysical Studies 1987 and 1988 should be of major interest to both the U.S. Navy and California Energy Company. The results over the Indian Wells Valley anomaly could be compared to results over the producing Coso Geothermal Field. This deep seated thermal anomaly may have an important influence on the deep water flow across Indian Wells Valley and therefore should be important to the EKCRCDC. Part of the reason for high flow rates in Indian Wells Valley may be the thermal plume centered 3 miles

west of the NWC Airport. (See Erskine Plate 1, Figs. 4a, 4b, & 4c, Pages 12, 13 & 14 of this report.)

The minimum vibroseis network of three lines proposed by W. H. Austin in 1987 is still a valid suggestion. Such a study would compliment the two line vibroseis study by California Energy Company, Inc., in the Rose Valley/Coso Geothermal Field Area.

Line 1: Would be from Walker Pass/Freeman Junction into the El Paso Mountains far enough to get a good definition of the Paleocene/Eocene Goler Formation and the underlying sedimentary rocks of the Cordilleran Miogeocline. (Refer to Figure 4 of the Erskine June 29 1989 report, Figure 3, Page 9 of this report) Since it is known that Hunt Oil Company has run at least part of this line it would be suggested that Hunt be contacted to see if they would allow purchase of their shooting. Hunt may be willing to farmout their Indian Wells Valley play and might be willing to sell their seismic work at a reduced price. Hunt indicates that they will be ready to talk about this in 30 to 60 days.

Line 2: Would be an east-west line from as far west in Sand Canyon as possible to the east side of Indian Wells Valley onto the Mesozoic granite outcrops of the Argus Mountain thrust block.

Line 3: Would be a north-south tie line connecting lines 1 & 2. (See Figure 8, Page 26 of this report). If the north-south tie line is done California Energy Company and the Navy might be interested in extending the line north up Coso Wash to tie with the three 1989 California Energy Company seismic lines in the Coso Geothermal Field.

These 3 vibroseis lines would control both the structure and stratigraphy of Indian Wells Valley showing details of the overthrust and slumped Sierra Nevada Mountains and the underlying Paleocene/Eocene Coso/Goler Formation deposited on the thick Paleozoic sedimentary rocks of Cordilleran Miogeocline.

Of great importance to Indian Wells Valley is the strong possibility that the Paleozoic rocks under the Goler Formation will be mainly massive Paleozoic limestones which might be an excellent deep aquifer where cavernous solution permeability has developed along fractures.

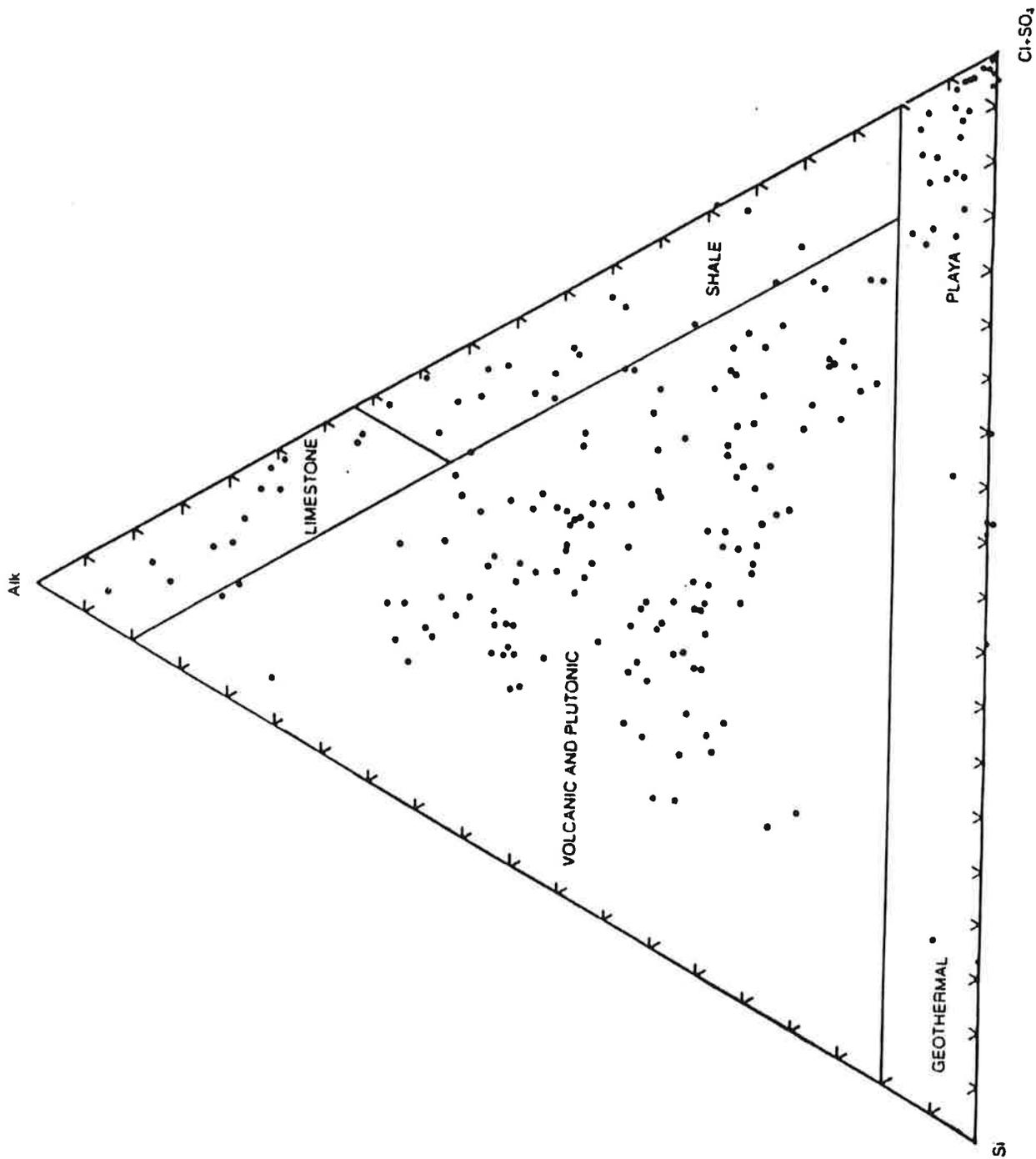


FIGURE 6 Triangular Plot of Water Types in the Indian Wells Valley and Other Areas.
Wheeler, 1989, Fig. 4

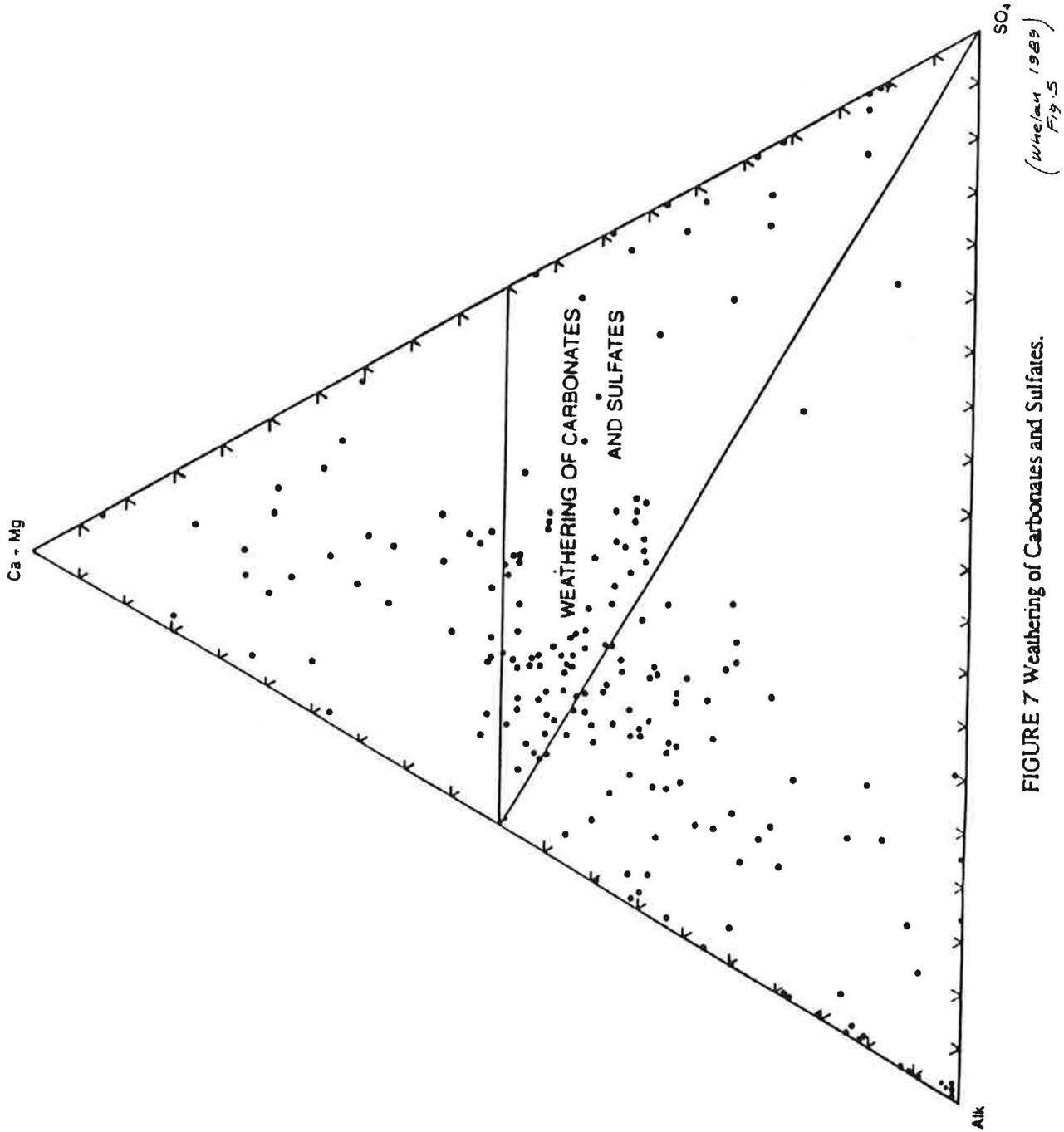


FIGURE 7 Weathering of Carbonates and Sulfates.

(Wheeler, 1989)
Fig. 5

Carbonate Springs in the granites of the High Sierras West of Indian Wells Valley suggest that the waters in these springs are saturated with calcium carbonate from circulation in the Paleozoic limestones underlying the Sierran granites. (Barnes and others 1981) Certainly the calcium carbonate in the Sierran Springs is not derived from the granite.

Additional support for the presence of Paleozoic limestones under Indian Wells Valley is the distribution of calcium rich waters. Dr. Whelan et al 1989 states that, "It appears that this diagram, (Whelan 1989 Figure 5, Fig. 7, Page 22 this report) developed for surface waters in the tropics, is not applicable to the groundwater environment of the desert in Indian Wells Valley as the majority of the points show a sedimentary relationship (Whelan Fig 4, Fig 6, Page 21 this report). Because much of the alluvium is composed of Sierran Rocks. which are granitic with lesser metamorphic rocks, one would expect the water to have exhibited an igneous association". However, if the high flow rates seen in the Coso Geothermal Field are a guide, it may well be that the high flow rates from the Sierran snowpack west of the crest down through highly fractured overthrust and slump faulted granites, through the Goler Formation into the Paleozoic limestones may be supplying the ground water evidence of a sedimentary relationship which surprised Dr. Whelan et al. (Appendix C) The horseshoe shaped area of sodium/bicarbonate/chloride water with patches of calcium/sodium bicarbonate/chloride/sulfate waters may overlie NE-SW and NW-SE faults which causes deep water circulation to surface and locally modify the groundwater and thus showing a sedimentary instead of the expected igneous association. Note that the NE-SW faults are parallel to similar faults that may be water feeders from the Wilson Canyon-Little Lake Fault zone into the Coso Geothermal Field.

Recommendations:

1. Long term accurate monitoring of Indian Wells Valley water wells on the basis of recommendations by Dr. M. C. Erskine and Mr. Ben Lofgren is essential. Until accurate well elevations are obtained and until systematic water level studies are made on the same dates during both the pumping and non-pumping seasons consistently over a period of several years, any conclusions made will be meaningless and misleading.

2. It is recommended that the US Navy, California Energy Company and the EKCRCD join to do a Curie Isotherm Study of the area from Owens Lake to the El Passo Mountains and from the Sierra Nevada Mountains to the Argus Range east of Indian Wells Valley. This area is 60 miles long by 25 miles wide and is about 60% on Navy land and the balance on California Energy Company and EKCRCD areas of interest. The cost for such a survey is estimated at \$110,000.

3. Three vibrosics lines as shown on the attached map are again recommended to control the position of the Sierra thrust front granites, the depth and location of the Miocene Coso/Ricardo, and Paleocene/Eocene Goler formation and underlying Paleozoic sediments, especially the Paleozoic limestones top of the Argus thrust granites and Paleozoic sediments under the Argus plate. Location of the suspected deep aquifers is vitally important in locating deep wells (6,000 feet to 8,000 feet) to test potential deep aquifers for Indian Wells Valley. Cost for a new survey if no portion can be purchased would be \$393,000.

4. Recommended deep wells to test for underflow from Rose Valley and the Sierra Nevada Mountains (Austin, 1986, photostructure density anomalies):

#1	NW1/4,	sec. 16,	T27S,	R38E,	MDBM,	Kern County, Ca.
#2	SE1/4,	sec. 3,	T26S,	R38E,	MDBM,	Kern County, Ca.
#3	NW1/4,	sec. 4,	T24S,	R38E,	MDBM,	Inyo County, Ca.
#4.	NE1/4,	sec. 5,	T25S,	R39E,	MDBM,	Kern County, Ca.
#5.	NE1/4,	sec. 8,	T28S,	R38E,	MDBM,	Kern County, Ca
#6.	SE1/4,	sec. 9,	T25S,	R38E,	MDBM,	Kern County, CA

The cost for one 8,000 foot water well might be \$700,000 depending on the amount of casing used.



Figure 8
 W. H. Austin
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Appendix

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Structural Investigations at the Coso Geothermal Area Using Remote Sensing Information, Inyo County, California

Remote sensing studies have been made in and adjacent to the Coso geothermal field using TM FCC satellite imagery, 1:100000 scale, U. S. Geological Survey orthophotos, 1:24000 scale, and proprietary black-and-white photography by California Energy Company, Inc., at various scales including black-and-white positive film transparencies at a scale of 1:6000. These studies have been made in an attempt to understand the complex geology seen on the surface and to try to improve the method of locating geothermal wells.

The tectonic history indicated by remote sensing, gravity, magnetic, refraction and reflection seismic studies indicates structure caused by a period of thrusting and folding followed by local and regional slumping and collapse, which is continuing today. During Sevier/Laramide orogeny, the Sierra Nevada Mountains were thrust eastward over Rose Valley/Indian Wells Valley. Relatively thin granitic/metamorphic plates were folded to form the Coso Range and thrust eastward over Coso Wash. In turn, the Argus Range to the east was thrust eastward over Panamint Valley.

As soon as topographic relief, developed by the thrusting, was high enough, the entire area started to collapse, in some cases using the original thrust planes for slumping. The granitic/metamorphic rocks forming the surface of the Coso Range anticline slumped eastward into Coso Wash and westward toward Rose Valley. The Sierra front slumped eastward into Rose Valley/Indian Wells Valley, and the entire range may have slid westward on the original thrust faults. The thin basalts on the east side of Coso Wash slumped westward into Coso Wash. Several basaltic eruptions of 3-4 million years ago used the zone between slump blocks as eruption sites. Regional slumping for the entire area toward the southeast is indicated on satellite imagery.

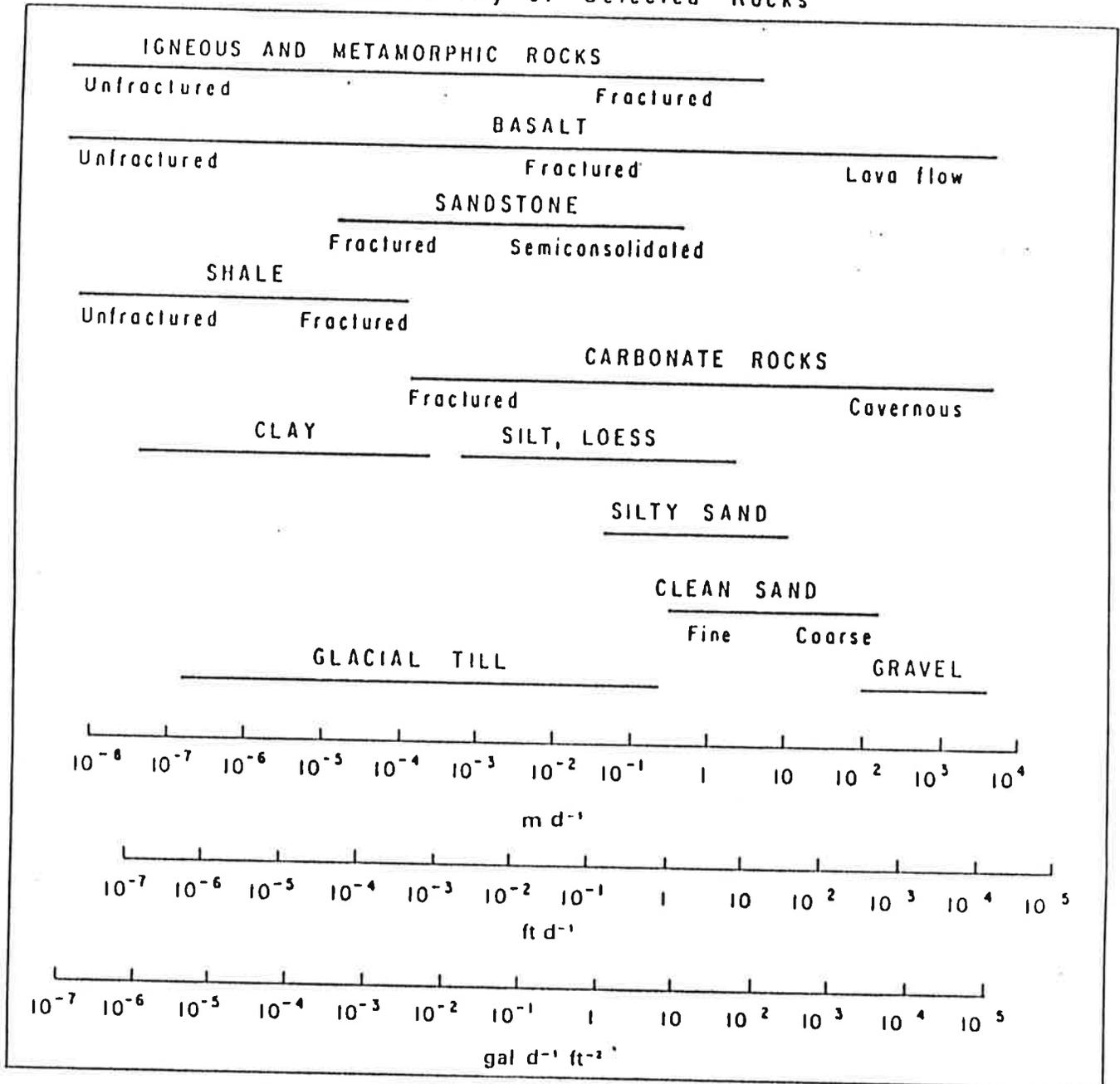
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Tectonic Setting of the Coso Geothermal Reservoir

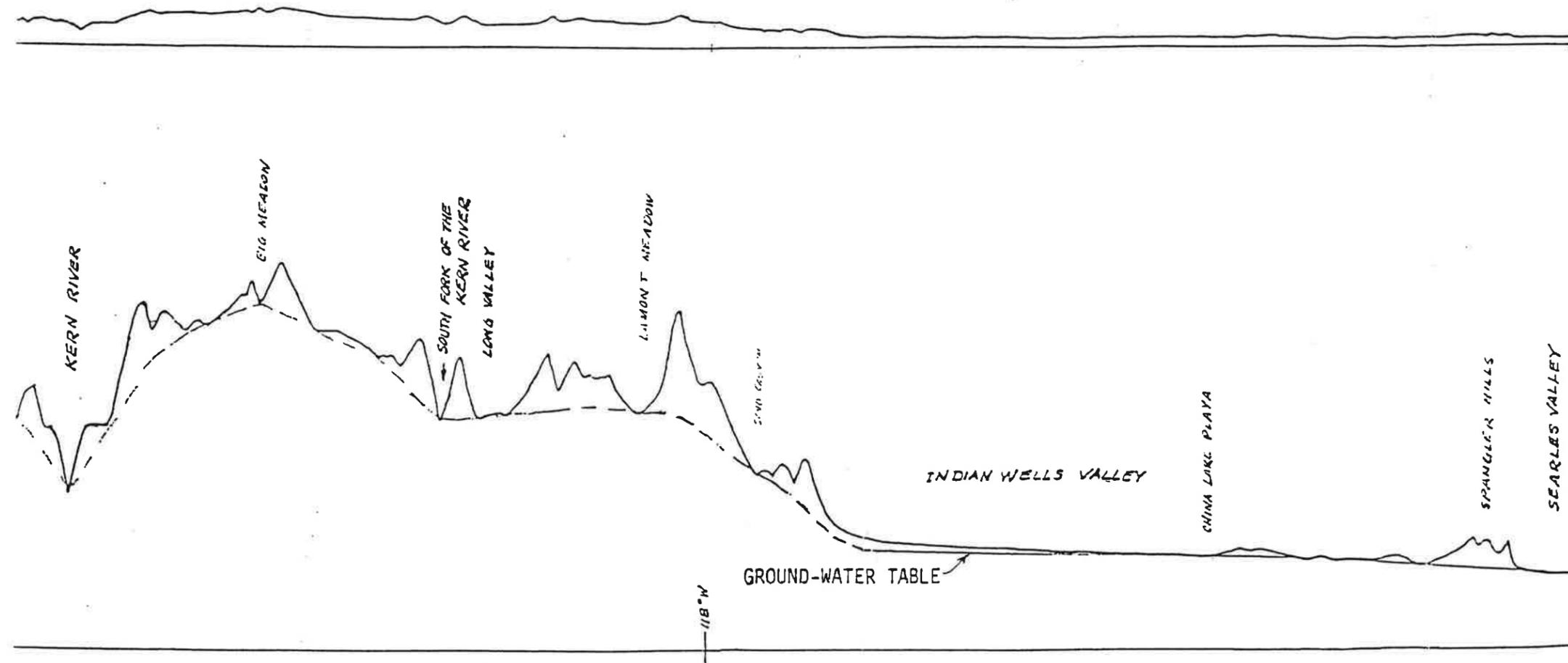
The Coso geothermal reservoir is being developed in Sierran-type crystalline bedrock of the Coso Mountains, a small desert mountain range just to the east of the Sierra Nevada and Rose Valley, which is the southern extension of the Owens Valley of eastern California. Optimum development of this reservoir requires an understanding of the fracture hydrology of the Coso Mountains crystalline terrain and its hydrologic connection to regional groundwater and thermal sources. An interpreted, conceptually balanced regional cross section that extends from the Sierra Nevada through the geothermal reservoir to the Panamint Mountains is presented. The cross section is constrained by new reflection and refraction seismic data, gravity and magnetic modeling, drilling data from the geothermal reservoir, and published regional geologic mapping. The interpretation presented in the cross section and the geochemistry of the reservoir fluids is used to argue that the geothermal system is a thermal bulge on an otherwise normal fracture-controlled regional groundwater flow. This groundwater flow starts from recharge areas in the high Sierra Nevada and Coso Mountains and moves toward the very low desert valleys to the southeast. The hypothesis also suggests that the low-angle intracrustal detachment of the Basin Ranges may be controlled by thrust structures developed during the Cordilleran, Sevier plus Laramide, orogenic event.

Appendix A

(Erskine Figure 2), Hydraulic Conductivity of Selected Rocks



From USGS Water-Supply Paper 2220



(FIGURE 8.) N72W TRENDING TOPOGRAPHIC PROFILE THROUGH THE SIERRA NEVADA AND INDIAN WELLS VALLEY.
 (Erskine 1969) INTERPRETED GROUND-WATER TABLE INDICATED.

