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Church
Dixie
Summary

April 27, 1979

MEMORANDUM

TO: H.P. Ross

FROM: R.W. Whipple

SUBJECT: Summary of the Dixie Valley Geothermal Area (Confidential)

INTRODUCTION

Dixie Valley lies within the Battle Mountain Heat Flow High of northern Nevada, between the Stillwater Range on the west and the Clan Alpine Mountains on the east. Dixie Valley Hot Springs lie 80 miles south of Winnemucca and 40 miles northeast of Fallon in a direct line. The basin to the west contains the Stillwater-Soda Lake KGRA and one to the east the McCoy geothermal prospect. Dixie Valley is a center of recent seismic activity. In 1954, earthquakes with magnitudes up to 7.1 caused the floor of Dixie Valley to drop by perhaps as much as 7 feet near IXL Canyon, 10 miles south of Dixie Hot Springs.

The hot springs of Dixie Valley have temperatures of up to 80°C. Maximum temperature estimated from geothermometry of these waters is 175°C. Fourteen miles to the north of the springs, a well is reported to have a temperature of 125°C at 110 meters. The Dixie Comstock Mine, between the hot springs and the well, is reported to be warm and nearby boreholes have elevated temperatures at moderate depths. All of the thermal anomalies in Dixie Valley lie next to the Stillwater Range on the west side of the valley. The greatest depth of test drilling for geothermal evaluation has been 1,500 feet (457m), where a maximum temperature of 97^{o}C was recorded. A well drilled by Sunco in the NW¼ Section 18, T 24 N-R 37 E is said to contain high temperatures (600^{o}F) and is discharging steam at the surface.

This discussion will be confined to the northern parts of the Stillwater Range, Dixie Valley, and the Clan Alpine Mountains between 39^{o} 45' and 40^{o} 00' of latitude. All of the Dixie Valley open-file data are confined to this area.

GEOLOGY

The following sources were used in compiling this summary of the geology of the Stillwater Range and the Clan Alpine Mountains: Speed, 1962; Speed, 1966; Speed and Page, 1964; Speed and Jones, 1969; Willden and Speed, 1974; and Page, 1965. Specific references will not appear in the geology text except where differences of opinion exist.

Dixie Valley is a northerly trending graben bounded on the west by the precipitous front of the Stillwater Range and high angle faults of large vertical displacements. The eastern part of the graben appears to ascend gradually in a series of step-faults of relatively small displacements to the foot of the Clan Alpine Mountains.

The oldest exposed rocks in both the Stillwater Range and the Clan Alpine Mountains are Triassic in age (Willden, 1974). A thick Triassic shale and siltstone unit is widespread, with a thickness greater than 20,000 feet in the Clan Alpine Mountains and from 5,000 to 10,000 feet (Page, 1965) in the Stillwater Range. The upper 3,200 feet of this unit in the Clan Alpine Mountains is 30%

to 50% carbonate rocks, with the uppermost exposures almost massive dolomite and limestone. This carbonate sub-unit is absent in the Stillwater Range, where the upper 200 feet of Triassic rocks are mainly coarse siltstone with considerable sandstone.

A Middle Jurassic quartz arenite (the Boyer Ranch formation), with a basal limestone and dolomite conglomerate, occurs in the Stillwater Range and in the western part of the Clan Alpine Mountians. In most places it is in thrust contact with the underlying Triassic rocks. This formation is intruded by a large complex of gabbroic rocks which forms a lopolith centered in the Stillwater Range and extending across Dixie Valley into the Clan Alpine Mountains. The only units which the gabbro intrudes are the quartz arenite, which crops out at the periphery of the lopolith, and comagmatic basaltic rocks within this annular zone. In places, quartz arenite occurs both above and below the gabbro and is, in turn, overlain by the gabbro's extrusive equivalent.

The quartz arenite was deposited shortly before the intrusion of the lopolith, and the thrusting which separates it from Triassic formations occurred before solidification of the intrusion. Thrust direction is radial to the magma conduit and displacements are probably less than five miles. The Middle Jurassic age attributed to the quartz arenite, the thrusting, and the gabbroic complex and associated extrusive rocks is based on K/Ar dating of intrusive constituents.

Tertiary and Quaternary volcanic rocks of a wide range of compositions occur in both the Stillwater Range and the Clan Alpine Mountains. Also common, from the same periods, are accumulations of lacustrine and fluviatile sediments.

No outcropping granitic rocks border Dixie Valley in the area of interest, but a body of Cretaceous(?) granite occurs on the west side of the Stillwater Range opposite Dixie Hot Springs. Worthy of particular note is a granodiorite intrusion cropping out in the Deer Lodge Canyon area on the west flank of the Clan Alpine Mountains about two miles south of latitude 39° 45'.

Cenozoic faulting, responsible for the Basin and Range topography, is believed to be generally younger than middle Pliocene and has extended through the Holocene. In 1954, faulting on the east flank of the Stillwater Range in the south part of Dixie Valley caused net vertical displacements of up to 7 feet.

GEOPHYSICAL CONSIDERATIONS

Magnetics

Aeromagnetic maps published by the U.S. Geological Survey, 1978, and the Nevada Bureau of Mines and Geology, 1977, cover the Dixie Valley geothermal area. These were flown at a barometric elevation of 9,000 feet and with 2-mile flight line spacings. Smith, 1968, conducted an aeromagnetic survey of Dixie Valley at 4,200 feet, barometric, with flight lines about 1½ miles apart on a square grid. In 1977 and 1978, Senturian Sciences, Inc., flew a number of multi-level lines across Dixie Valley near the known thermal anomalies. Data from the Senturian surveys are presented as differences in gammas between flight levels with no total field values given. EDCON, 1976, conducted some ground magnetometer work in Dixie Valley, mainly near the flank of the Stillwater Range.

In the Dixie Valley area of interest, the oldest rocks, Triassic, are not reported to include volcanic or metavolcanic rocks which we might expect to be very magnetic, so that we may tentatively consider them to be neutral in a magnetic sense; especially since many of the younger rocks have such strongly magnetic characters. The gabbroic complex and comagmatic mafic volcanics cause large magnetic disturbances (EDCON, 1976, and personal communications). Also, many of the more mafic Tertiary and Quaternary rocks are very magnetic. Late Tertiary basalts in the southern Stillwater Range produce anomalies of over 3,000 gammas at 500 feet above the ground (personal communication).

Determinations of basement topography require that rock parameters remain constant within the assumed geometric model. Since lateral apparent susceptibility variations are extreme in adjacent mountain ranges, we expect this to be the case in Dixie Valley as well. Smith, 1968, avoided this problem by half-slope depth determinations on individual anomalies in the valley to prepare a topographic map of the magnetic basement. This basement we assume to be composed of Tertiary and Jurassic igneous rocks. Smith states that his depths compare well with those determined independently from gravity and seismic refraction studies (reference not available at this writing). This study supports the view that the basement rocks of Dixie Valley form an asymmetric graben roughly parallel to the valley axis. The deepest graben block is approximately three miles wide and lies under the western half of the valley. Smith calculated the maximum depth to the magnetic basement as about 6,000 feet.

Near the east side of Dixie Valley, in T 22 N-R 36 E, lies a broad magnetic high. At 700 feet above the terrain it has an amplitude of 500 gammas. ~~Speed~~ Smith, 1968, in an attempt to test the geologic view that the Stillwater lopolith may underly the area, has offered a solution of a horizontal tabular gabbroic body overlain by an erosional volcanic remnant. He suggests the alternate possibility of a volcanic cone over a tabular gabbroic intrusion. Senturian, 1977, maintains that it is a deep-seated gabbro intrusion. Smith's estimate of the depth to the top of the anomalous body is between 200 and 500 feet; Senturian, 1,400 feet. Smith's depth is comparable to a depth obtained by seismic refraction (reference being sought by ESL). I take the position that this anomaly is most probably due to a deep-seated intrusion, closely related to a Cretaceous(?) granodiorite cropping out in the Deer Lodge Canyon area of the Clan Alpine Mountains. On an aeromagnetic map by Zeitz, et al, 1978, the anomaly over the Deer Lodge Canyon outcrop and the one in Dixie Valley are outlined by a common magnetic contour.

Of the magnetic interpretations of the Dixie Valley area, I consider Smith's to be of high quality, even though I do not agree with his suggested solution for the broad anomaly in T 22 N-R 36 E. EDCON, 1976, has little to say about their magnetic map, relying on a gravity survey for basement depth calculations. Senturian, 1977, 1978, interpretations seem devoid of an appreciation of the known geology of the area. They attribute all unusual magnetic gradients to heat sources, without regard for the geometry of the probable source bodies or whether or not ferromagnetic rocks are present which extend across the Curie point isotherm. Until independent support of their conclusions appears, I suggest they be treated with skepticism.

~~GRAVITY~~ Gravity

Erwin and Berg, 1977, and Erwin and Bittleston, 1977, have prepared regional gravity maps which cover the Dixie Valley area of interest. EDCON, 1976, has conducted a much more detailed survey of the Humboldt Salt Marsh and the western side of Dixie Valley. Unfortunately, three east-west interpretive profiles which should accompany the EDCON report were not delivered to ESL. The EDCON report states that faulting on the west side of Dixie Valley is quite steep compared to faulting on the east side. The deepest valley fill occurs in Sections 7 and 8, T 22 N-R 36 E. This depth (EDCON) may amount to 7,000 feet or may be as great as 10,000 feet (this should not be confused with the "magnetic" basement of Smith). A major basement structural high indicated by gravity correlates with the broad magnetic high mentioned in the last section.

MAGNETOTELLURICS

Senturian, 1978, has conducted a magnetotelluric survey along the west side of Dixie Valley. This survey consisted of 27 stations at which one component of the telluric field was measured. A one-component magnetic and an orthogonal telluric field were measured at a base station. Apparent resistivities were calculated from the telluric field at each station, normalized to the base station, and the base station magnetic field. These calculations were performed over various frequencies from 25 to 0.01 Hz.

Senturian interprets a high conductivity zone at depth on the basis of 1D modeling. Contours of depth to this region appear on one of their illustrations. This interpretive surface rises to depths of less than 8 km at three locations on the west side of Dixie Valley. These are identified by Senturian as the Stillwater, Dixie Site, and Mine "heat source" anomalies.

A serious problem with Senturian's 1D interpretations is that all of their telluric stations lie near at least one lateral discontinuity of major proportion. This is at the large front fault of the Stillwater Range, which places Quaternary deposits directly against Mesozoic rocks. Perhaps a better indication of prospective geothermal areas is an AMT survey, Senterfit, et al, 1976. One low resistivity zone from AMT lies near Senturian's "Mine Anomaly".

~~TEMPERATURE GRADIENTS~~ Temperature Gradients

Temperature gradients have been recorded for 22 boreholes in Dixie Valley, but only 6 temperature logs are available for examination. Gradients calculated from these logs do not match well with the other values and it is difficult to construct a reasonable contour map. It appears, however, that there are three separate thermal anomalies on the west side of Dixie Valley. These center in the following locations: Section 15, T 24 N-R 36 E; Section 14, T 23 N-R 35 E; and Section 5, T 22 N-R 35 E. This last location is based on the surface water temperatures at Dixie Hot Springs.

~~MICROEARTHQUAKES~~ Microearthquakes

A microearthquake study of Dixie Valley was conducted over a period of 20 days by MicroGeophysics, 1976. MicroGeophysics proposes an interpretation based on fault plane solutions wherein the west side of Dixie Valley is cut by northwest-trending faults with oblique slips alternating with a northeast-trending dip-slip zone. The northeast-trending normal fault zone is subparallel and spatially close to the boundary fault of the Stillwater Range. An intersection of these postulated fault systems occurs near Dixie Hot Springs.

~~REFRACTION SEISMIC~~ Refraction Seismic

Several references to a refraction seismic survey of Dixie Valley by Meister

1967, have been cited. This publication is not available for review but we are attempting to track it down.

RECENT DEVELOPMENTS

Messrs. Jere Denton and Dick Jodry, representing Southland Royalty Company, have informed us of some recent developments in Dixie Valley and of Southland's views concerning their significance. A new aeromagnetic survey has been completed of Dixie Valley and part of the Stillwater Range. This survey was flown in two blocks: one at 5,500 feet ASL over the valley and another at 7,500 feet ASL over the mountains. Line spacings were one mile. A region of large magnetic variations was found to lie along the eastern side of the valley where the surface is covered by Quaternary deposits. These variations are believed to be caused by rhyolitic Tertiary volcanics which have been encountered in drilling. Two large fan-shaped flows under Quaternary cover are postulated here. Based on magnetic interpretations, and/or temperature data in 1-meter holes, Southland is excited about the potential of the east side of the valley.

Southland has made temperature measurements in 1-meter holes on a wide grid spacing over a sizeable portion of Dixie Valley between 39^{o} 45' and 40^{o} 00' north. They plan to do mercury analyses of soil samples from these holes. A thermal anomaly observed in 1-meter holes in Sections 2, 3, 10, and 11, T 22 N-R 36 E (gradient 6.6^{o}F/100 feet) is considered to be very significant by Southland. They are interested in obtaining a property position here.

A magnetotelluric survey, consisting of 41 stations recording three components of the magnetic field and two of the telluric field, is planned by

Southland for central Dixie Valley from T 23 N to Sou Hot Springs. Sou Hot Springs have recently attracted the active attention of exploration groups. They lie in T 26 N-R 38 E at the extreme northern end of Dixie Valley (at 40^{o} 05' N). They abut the Sou Hills, an apophysis of the Stillwater Range.

Shortly before this writing, drilling was begun in Section 14, T 23 N-R 35 E on a hole planned for 8,000 feet. Another deep hole is planned for either Section 16 or Section 21, T 24 N-R 36 E.

Cuttings from six gradient holes, ranging from 500 to 1,500 feet, were shipped by Southland to ESL some weeks ago.

DOE SUPPORTED PLANS

Reflection Seismic

Three reflection seismic profiles are planned for the western part of Dixie Valley. Two of these profiles are to extend outward from the Stillwater Range for approximately six miles and the third is to cross these lines well out in the valley. Line positions are not firmly established and it may be that considerable adjustment must be made to avoid foul ground in the Humboldt Salt Marsh. Southland may wish to extend one seismic line, at their own expense, to cross the temperature anomaly in Sections 2, 3, 10, and 11, T 22 N-R 36 E. Estimates of the cost of this survey range from \$100,000 to \$150,000.

Geochemical

Two blocks of ground held by Southland on the west side of the valley are of particular interest to them. Deep drill holes are planned on both blocks.

One block lies at the Dixie Comstock Mine in T 23 N-R 35 E (Dixie Site MT Anomaly) and the other includes all or parts of Sections 16, 17, 20, 21, and 22, T 24 N-R 36 E (Mine MT Anomaly). Each covers an area of about four square miles. Soil samples for mercury analysis are to be collected at about 100 foot intervals along traverses normal to faulting in each of these blocks. On selected traverses, arsenic analyses will also be made. Exact positioning of these geochemical traverses will be determined when the necessary structural information has been supplied by Southland. Between 600 and 800 samples are to be analyzed. Costs are expected to be between $10,000 and $15,000.

Self Potential

A self potential survey is planned which is to consist of a series of profiles along the west edge of Dixie Valley and normal to the Stillwater Range front. These traverses will be tied together by a single profile extending along the mountain front. Observation intervals are to be approximately 100 meters. Estimated cost for this survey is $5,000.

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April 27, 1979

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