GL02198

TUSCARORA GEOPHYSICS

Preliminary Report

27 January 1980

by

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TUSCARORA GEOPHYSICS

Active and passive electrical surveys, gravity and magnetic mapping, passive seismic monitoring, and heatflow measurements comprise the geophysical endeavor of the Tuscarora project. The results of the operations are shown in Figures 1-5, in a manner so that direct comparison may be made among the various anomalies observed. Where possible, geophysical deductions are related to the known geological features.

Heatflow

AMAX drilled and logged 38 wells between 40 and 600m deep to produce a map of heatflow shown in generalized form in the overlay, Figure 1A. The zone of highest heatflow (as great as 49hfu at Hot Creek) occupies the center of the property and conforms with the areas of a near-surface zone of low electrical resistivity, alteration, and in some places silica deposition. A comparison with the geologic map shows evidence of control by structural features, particularly the northeastward Midas trend, that intersects the Independence range bounding fault at Jack Creek. The zone of elevated heatflow nowhere drops below 3.8hfu in the outcrops, so that the pattern there is really not fully delimited. In the alluviated Independence Valley, however, heatflow drops to background readings of 2 and less.

Heatflow values were determined from measured and estimated thermal conductivities, based on cuttings, and from carefully logged temperature gradients obtained at least 30 days after drilling. In most cases, the deepest portion of the log was used to compute heatflow values.

Magnetics

An aeromagnetic survey was flown by Geometrix at 9000ft (CBA) along east/west flight lines spaced one mile apart. At least three major magnetic anomalies are evident (Figure 2). Along the north edge of the map are two closed circular magnetic highs (A and B on map) which are most likely due to intrusions. A narrow zone of high magnetic gradient extends from the bottom-center to the upper left corner of the map (from C to D). The area southwest of this gradient is a structural and magnetic high. The area on the northeast side of this gradient is generally a structural and magnetic low. The last major magnetic anomaly is the most poorly defined of the three. It is composed of loosely connected linear trends of magnetic intensity contours. A definite zone of these linear trends, 8km wide (E-F), extends from the southwest corner to the northeast corner of the aeromagnetic map. These trends are probably related to faults associated with the Midas trench. Initial results strongly indicate that the magnetic anomalies are caused not by the exposed volcanic rocks but by structural relief and magnetization contrasts within the underlying rocks. A north/south trending, 1.5km wide, alteration zone exists along Hot Creek (G). The magnetic profile inversions indicate a severe in situ destruction of magnetization at least 2km deep in this zone.

Gravity

The complete Bouguer gravity map shows that the Independence Valley graben (A, Figure 2A) extends northward across the Midas Trench (B-C). Faults divide the graben into several blocks which appear as connected closed gravity lows. The deepest part of the graben (~3km) appears to be about 1.5km north of the Spanish Ranch. The zone in which the graben and trench intersect contains a small central horst which is nearly surrounded by graben blocks (D). This pattern suggests a possible collapse structure with a domed center. Within the intersection zone, faults related to both tectonic features develop a well defined orthogonal pattern. The gravity low associated with Independence Valley graben continues off the northwest corner of the gravity map (E) toward the Snake River Plain. On this map the Midas trench is characterized by gravity lows and gradients which indicate that the related faults have a northeast/southwest strike direction. Two dominant fault zones indicated by the gravity data occur along the west side of the Independence Mountains (F to C) and along the interior of the Tuscarora Mountains (B to E).

Seismic monitoring

A 12-day microearthquake survey was conducted during September 1978 by MicroGeophysics Corporation, utilizing natural seismicity, teleseisms, and blasts recorded on a moving array of four to eight stations occupying 29 different sites. A total of 108 microearthquakes having magnitudes greater than minus 0.5 were recorded, of which 103 occurred during one day. Figure 3 shows the distribution of epicenters determined from a model of linear increase of velocity with depth. In general the depths ranged between 3 and 13km; mostly below 8km. Primarily vertical faulting with a slight SSW dip is exhibited along a WNW fault trend having a strong right-lateral strike-slip component.

Strain release is depicted by the two generalized contours of Figure 3A, in units of ergs$^{\frac{1}{2}}$x10^{-5}. Most of the movement occurred at the intersection of Jack Creek and Independence Valley. The strain release pattern is dominated by the 2.44 magnitude earthquake at the north end of the basin.

Poisson's ratio values greater than 0.35 have been interpreted elsewhere as indicators of fracture permeability within geothermal reservoirs. Here, the ratios are generally normal across the map (Figure 3B), except in the north end of the basin where they exceed 0.28 and reach a high of 0.35. Because of the coincidence of the outline with the basin, these values are attributed to valley fill.

P-wave delays appear over lower velocity media, such as alluvial fill, highly fractured or altered zones, and partial melt or magma. Figure 3B contains a generalized qualitative plot of abnormal P-wave behavior based on arrivals from 5 teleseisms and 2 distant shots. The delay zone underlying the northern end of the Independence Valley can be attributed at least in part to alluvium. A second slow zone is seen west of Hot Sulphur Springs and occupies a magnetic low. A third delay occurs just north of Chicken Creek Summit. The latter two anomalies might be related to alteration zones.

A narrow "ridge" of P-wave advance transects the map from SW to NE, with an interruption in the vicinity of the hot springs. Its occurrence along the axis of highest heatflow suggests that it may be due to silicification along fracture zones that control the geothermal fluids. The advance zones lying to the west and east align with the boundaries of the Independence graben and can be attributed to denser Paleozoic and PreCambrian rocks at depth, or outcropping. The same can be said for the seismic advances at the northern boundary of the depression. Alternatively, one might conceive of the entire central area as being a zone of seismic delay due to lesser crustal thickness and heating at depth.

Electrical Surveys

A self-potential survey was run by MicroGeophysics Corporation along eight EW section lines across an area of approximately 16x20km. The salient features are depicted in Figure 4. Most notable is the transition from positive to negative readings that occupies the axis of the heatflow high and a series of NE trending faults. R. Corwin views this feature as a plane of generation, though the actual mechanism--heat, fluid movement, or electrochemical action--is uncertain. In any event, a positive prong extends along Chicken Creek leading one to infer that the properties associated with the heatflow high may extend in that direction as well.

The SP negatives of the Independence range are typical of the existing Western-facies graphitic rocks, notably the Valmy formation. Mineralization, known to be present near the SE anomaly may also play a part. Several dipolar anomalies, indicated by + and - signs on the map are developed across bounding faults. Mapped sulfide occurrences may account for the dipole at Jack Creek, but cold or warm fluid circulation may play a role in all of these.

A dipole-dipole resistivity survey was conducted by Mining Geophysical Surveys, Inc. along the three lines of Figure 5A. Dipoles of 610m were extended to n=5 spacing. The most conductive zones (less than 8m) appeared across the central zone of high heatflow and along the western margin of the survey. In both cases the conductor was capped by a more resistive layer. The central anomaly can be attributed to alteration products--probably clays--known to underly the area, with possibly a component due to thermal waters. The more resistive cap may be due to the sinter and travertine present around the springs, and, elsewhere, to the absence of ground water near the surface. The bounding faults of the Independence range show up conspicuously as electrical contacts between the Paleozoic rocks and the aforementioned conductor and valley fill.

A magnetotelluric survey was performed by Terraphysics along approximately the same line as the resistivity survey. It utilized a total of 30 stations of which 11 were magnetometer/electrode bases and 19 were telemetered satellite stations made up of two electrode pairs oriented at right angles, and serving as remote references. Data were collected in the frequency band between .01 and 10hz, and inverted to depth sections by the well-known Bostick inversion method.

The exercise revealed two principal conductors (Figure 5). The shallow zone (0.5km) occupies the center of the thermal anomaly and correlates with the near-surface conductor seen by the resistivity survey. On the northern line, however, it extends further west than was evident in the previous survey; and to the south--under the Owhyhee River--the conductor did not appear above one km depth. Again the resistive block of the Independence range was evident at all depths in the vicinity of Jack Creek.

Noteworthy is an apparent deep conductor (1Ωm) that rises to a depth of 5km beneath a north/south zone from the northern end of the valley to at least Chicken Creek summit. This zone correlates with high heatflow, fault intersections, microearthquakes, gravity lows, an SP high, and P-wave anomalies. Before we conclude, however, that the MT is seeing here a deep heat source or reservoir, the data should be subjected to scrutiny and modelling.

Of further interest is the anomalous behavior under the first drill site, adjacent to the major hot spring activity in Hot Creek. Here a resistive block below 1km, evident under stations to the east and west, appears to be interrupted beneath Hot Creek, thus allowing possible communication between the shallow conductive zone and a deep conductor (here at 10km). The N/S alteration zone seen in the magnetics occupies this gap, and suggests permeability to considerable depth.

Note

The geophysical information summarized above should be tied to a memorandum by H. D. Pilkington dated 6 December 1979, entitled "Geological Summary of the Tuscarora Area, Nevada." Sections of this report concerning gravity and magnetic surveys were prepared by Fred Berkman, the remainder was by Arthur L. Lange. Contractors' reports covering the surveys discussed are the following:

Microgeophysics Corporation

Tuscarora Seismicity. 1978.

Self-potential Survey, Tuscarora, Nevada. 30 July 1979.

Tuscarora, Nevada Gravity Survey. 1 January 1980.

Mining Geophysical Surveys, Inc.

Resistivity Survey, Tuscarora Project,
Elko County, Nevada. 17 August 1979.

Terraphysics

Telluric-Magnetotelluric Survey at Tuscarora Prospect,
Elko County, Nevada. November 1979.

AMAX EXPLORATION, INC.
A SUBSIDIARY OF AMAX INC.

GEOTHERMAL BRANCH

INTER-OFFICE MEMORANDUM

SUBJECT: Geological Summary of the Tuscarora Area, Nevada

DATE: December 6, 1979

cc: Scott Sarber
A. L. Lange

TO: H. J. Olson

FROM: H. D. Pilkington

INTRODUCTION

The Tuscarora prospect is located at the north end of Independence Valley approximately 50 miles north-northeast of Elko, Nevada. Independence Valley is a fault basin on the west side of the Independence Range, and represents an area where the Basin and Range structures abut against the Snake River downwarp. The thermal manifestions include two groups of hot springs which issue from a north-northeast trending linear zone in the low hills located between the Independence Range and the Tuscarora Mountains at the north end of Independence Valley.

ROCK DESCRIPTIONS

Paleozoic Rocks

The Independence Mountains are composed of a thick sequence of Paleozoic sedimentary rocks. The present day Independence Range area was located near the tectonic boundary between lower Paleozoic miogeosyncline to the east and the eugeosyncline to the west. A considerable thickness of limestones, cherty limestone, siltstones and quartzites of the Eastern (mio-geosynclinal) facies accumulated from Cambrian to early Devonian times. To the west in the eugeosyncline up to 50,000 feet of chert, siltstone, quartzite and volcanics were deposited as the Western facies. During late Devonian time the rocks of both sequences were folded, uplifted, and the Western facies rocks were thrust eastward along the Roberts Mountain thrust over the miogeosynclinal rocks.

The Carboniferous and Permian sediments deposited in the area of the Independence Mountains consisted of siliceous rocks and associated volcanic rocks of the Upper Paleozoic eugeosyncline. The section probably exceeds 10,000 feet, but may have some sections duplicated by faulting and isoclinal folds.

Tertiary rocks

The Tertiary rocks in the Tuscarora area are a thick sequence of interrelated sediments of fluvial and lacustrine origin with tuffs, crystal tuffs and minor flows of volcanic origin. The rocks range in age from Late Eocene or Early Miocene (34-41 my) to Late Miocene to Early Pliocene (6-17 my). In a very general way the oldest Tertiary rocks in the area consist of several hundred to perhaps as much as a thousand feet of ash flow tuffs and crystal tuffs with some agglomerate near the base. The rocks are rhyolitic and contain crystals of quartz, sanidine, hornblende and minor pyroxene. Local structural basins developed during this period of volcanism in which fluvial and lacustrine sediments were deposited. The thickness of the intercalated sediments increase northward into Bull Run Basin where 2000 to 5000 feet of sediments occur. The younger Tertiary rocks are dominantly volcanics varying from andesite to rhyolite in composition and from 6-17 my in age. Locally the younger Tertiary rocks contain ignimbrite, tuffs and sediments which are tentatively correlated with the Idavada volcanics of Idaho.

The Tertiary volcanoclastic rocks and tuffaceous sediments commonly show moderate to strong argillization which may in part be diagenic but is often hydrothermal. The argillization is primarily related to the devitrification of the volcanic glass and volcanic ash.

Quaternary Deposits

The flanks of Independence Valley contain rather extensive deposits of terrace gravels that are related to modern streams. The deposits are relatively thin, usually 30 to 60 feet thick, with a coarse bouldery surface.

Recent valley fill and alluvium occur along all major valleys. Siliceous sinter has been deposited by the Hot Sulphur Springs for a considerable period of time. The older hot spring deposits are east of the present day springs. The siliceous sinter cements the terrace gravels along the banks of Hot Creek and new sinter mounds are forming around the present spring orifices.

STRUCTURE

The Tuscarora area has had a long and complex structural history. The Late Paleozoic Antler Orogeny resulted in isoclinal folds with East-West fold axes. The deformation culminated in major low-angle thrusts which carried the western facies rocks many miles eastward over the miogeosynclinal facies. The thrust is exposed in the Independence Mountains and has been mapped as a part of the Roberts Mountain Thrust.

Within the Tuscarora area the only evidence of Mesozoic tectonism is the presence of several dioritic to granodiorite intrusions east of the prospect. The granitic intrusions are of probable Cretaceous age.

The earliest Cenozoic structures in the area are related to the volcano tectonic features associated with the 34-41 my old crystal tuffs. The granitic rocks exposed a few miles to the west of the Tuscarora mining district have been dated as 38.4 my which coincides with the radiometric dates on adularia from the veins at Tuscarora mining district. Contemporaneously with the early volcano tectonic activity the area was subjected to extensional forces resulting in Basin and Range type structures. Movement on the north-south to the north-northeast trending normal faults continues to recent times as evidenced by the scarps in the alluvial fill of Independence Valley.

The Basin and Range structures are offset by a broad zone of northeast trending left lateral faults known as Midas Trench lineament system. Displacements on these left lateral faults began in mid-Miocene time and continues to the present. Some dip slip movement occurs on these faults as well.

Within the Tuscarora prospect several northwest trending faults have been mapped which offset the Basin and Range structures. The northwest trending faults become the dominant structural grain northward into the Owyhee uplift. Movement along these faults is dominantly right lateral, but may have a strong dip slip component. In the Tuscarora area movement on these faults apparently began about 15 my and has continued to the present.

H. D. Pilkington

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