STEAMBOAT HILLS, NEVADA.

STRATIGRAPHIC TEST 13-5

Summary of Geology, P.C. van de Kamp, March 1989.

Stratigraphic test well #13-5 was drilled to 2470 ft. depth in November and December 1988. Bottom hole location is about 188 ft. north of the surface location. This northward drift may have been caused by fractures in the rock deflecting the drill bit. The well was drilled entirely in metamorphic rocks of the Triassic-Jurassic Peavine Sequence of Bonham and Papke (1969). In the interval 304-542 ft., a few short cores were taken, from 646 ft. to total depth, continuous cores were taken. These have been logged for lithologic and structural information which is summarized on the attached strip log. Selected intervals were also sampled for assay evaluation by W.T. Cohan. The assay results are reported separately.

The core logging indicates that the rocks are metamorphic schists with poor to fair compositional layering. There are common fractures with dips of less than 10 degrees to vertical. Most of these are filled with calcite and/or chlorite. They range from less than 1 mm. to 10 cm. wide with many in the 1 to 3 mm. width range. In a few cases there are open vugs within otherwise cemented fractures or joints. No fractures with significant open, permeable zones were found in the cores. However, in the cores between 300 and 700 ft., very fine clays are found in some fractures; these may be in situ from deep weathering or they may have infiltrated in water along permeable fractures. Apparent fault zones with brecciated rock, slickensides, and clay gouge in intervals of 10-70 cm. thickness with dips of 40 degrees to vertical occur at many depths. These do not appear to be very permeable because of the clay gouge.

Rocks from the surface to 700-800 ft. depth are somewhat soft and have common iron staining indicative of weathering. The rocks below 800 ft. depth, although grossly similar to the shallow samples, are quite hard and likely weathering effects are absent. The static water level is estimated to be about 900 ft. below the surface in this well.

Thirty seven samples of core were analyzed in thin section to determine rock mineralogies, microtextures, and alterations. In general, the rocks are rather consistent from top to bottom in the well. Their characteristics are described and interpreted below.

Essentially, the rocks are composed of plagioclase (albite-oligoclase), quartz, and biotite with or without muscovite, chlorite, and K-feldspar. Porphyroblastic garnet is present in some samples below 1300 ft. depth and andalusite (var. chiastolite) is common in the sample at 2382 ft. depth. Accessory minerals include pyrite, epidote, apatite, zircon, calcite, sphene, zoisite, and amphibole. The textures are poorly to well layered schistose in thin section. There are common relict phenocrysts of quartz and plagioclase which are partly recrystallized and patches of extremely fine-grained quartz and feldspar which may represent original glassy fragments in the pre-metamorphic rock. A possible recrystallized carbonate fossil fragment (bryozoan?) was seen in the sample at 1373 ft. depth. These rocks are thought to be metamorphosed volcanic tuffs and flows of dacite-rhyolite composition, originally deposited in a marine environment, which have been metamorphosed in Greenschist to lower Amphibolite facies conditions. The andalusite bearing rocks may be in the Hornblende Hornfels facies of Turner (1968); this suggests proximity to the contact of the granodiorite intrusion which is penetrated in nearby wells (83-A6 and 21-5).

The fracture fillings are mainly calcite and chlorite. In many fractures, there is chlorite on the margins and calcite in the center of the vein type filling. Commonly the calcite is layered parallel to the sides of the fracture suggesting multiple episodes of vein deposition. In some cases, the fractures are filled only with chlorite with the flat crystals oriented at high angles to the sides of the fractures. In most fractures the minerals show no signs of shearing indicating no movement after fracture filling. Some earlier filled fractures (veins) are broken and offset by later fractures.

At various places in the cores, there are intervals of highly altered rock ranging from 1 to 10 meters or more in core length. These are commonly light grey-green to nearly white. In some cases, the alteration is clearly concentrated along fractures which are now tightly cemented with secondary alteration minerals such as quartz and epidote. A notable feature of these rocks is the abundance of cinnabar associated with them. In thin section there are relicts of original minerals and textures which show that these originally were metamorphic rocks similar to the unaltered rocks. Now the altered rocks are composed largely of quartz, epidote, zoisite, clinozoisite, sericite, chlorite, and carbonate. It appears that there has been extensive hydrothermal alteration which has caused replacement of feldspars and micas as well as carbonate. Essentially there has been leaching of large quantities of sodium, iron, and magnesium and very likely, associated trace metals including Ti, Cr, Cu, Co, Zn, Ag, Au, Pb, and Hg as well as Cl, F, S, and As. The mineralogy suggests the following general reaction:

Original metamorphic rock + hydrothermal alteration yields altered rock; stated mineralogically this is:

Quartz + plagioclase + biotite + calcite + hydrothermal alteration yields Quartz + epidote + sericite + calcite.

Much of the original calcite was consumed in the development of epidote minerals so the altered rock contains much less carbonate. By analogy with similar situations where reaction temperatures have been estimated (Vikre, 1986), the hydrothermal alterations in the deep subsurface at Steamboat Hills probably occurred at 200 to 300 degrees C. The fate of the leached ions is not well known but there must be deposits of iron-rich minerals somewhere and the waters evolving from the system contain abundant Hg, Sb, S, CO_2, Cl, As, B, Si, Na, and Mg.

The time of the inception of this hydrothermal alteration is uncertain. Silberman et al. (1979) performed isotopic age dates on unaltered and altered rocks at Steamboat Hills to determine the timing of hydrothermal alterations in outcrops. They concluded that the hydrothermal activity started about 2.5 million years ago and has continued, possibly intermittently, to the present. The information gathered from well 13-5 is not inconsistent with this interpretation.

Temperature was logged in the well on January 7, 1989, three weeks after completion of drilling. Logging stopped at 2394 ft., short of the drilled depth because of an obstruction in the tubing in the well. At 2394 ft., the measured temperature is 400 degrees F; this was confirmed by a second survey two weeks later. The profile obtained (figure 1) is similar to those for producing wells 83-A6, 21-5, and 23-5. This well reached the top of the productive interval; with projection of the gradient found, temperatures of 430 degrees F may occur at about 2600 feet depth well within the productive zone. Thus this test is very encouraging for indicating a possible productive location.

REFERENCES

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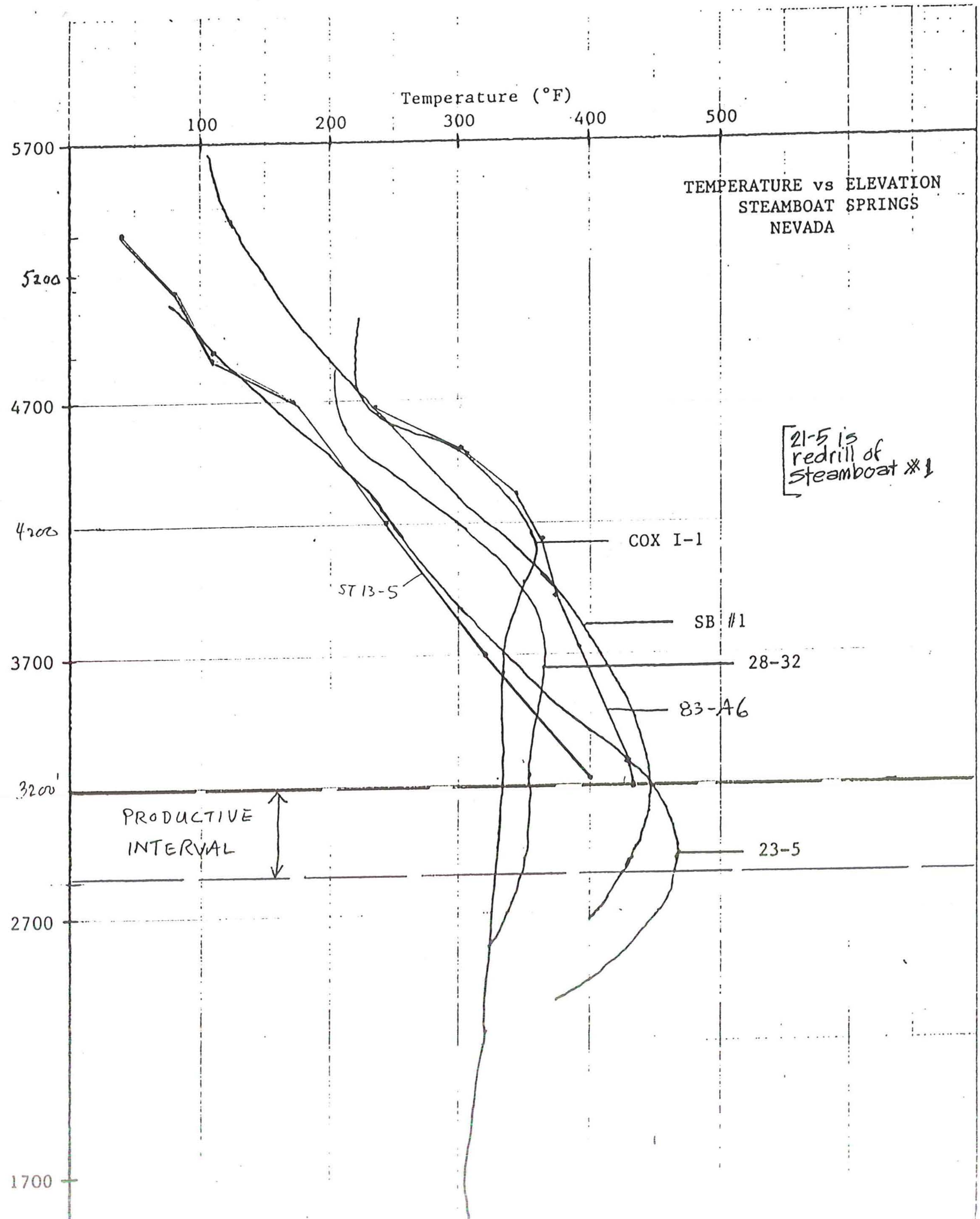

Figure # Temperature versus Elevation Above Sea Level for the Steamboat Springs production wells