metamorphosis progressed. *R. pipiens* tadpoles had only the 4.3*S* component in its red blood cells and did not show the heavier 7.0*S* component; the adult *X. laevis* had only the 4.3*S* component initially, but apparently formed a limited amount of the 7.0*S* hemoglobin when the lysate of the red cells was stored under refrigeration for several days. Average molecular weights indicated 68,000 for the hemoglobin of *R. grylio* tadpoles and 68,000 and 136,000 for the two principal components for the frogs of this species.

Certain of the red blood cell components detected in the ultracentrifuge were separated by starch-block electrophoresis in sufficient quantities for further study and identification. The small amount (less than 10 percent) of the 2.7*S* and the predominant (more than 90 percent) 4.3*S* ultracentrifuge components of the red cells of the *R. grylio* tadpole corresponded respectively to the slower and faster moving bands visible on starch-block electrophoresis of the lysate. The 4.3*S* and 7.0*S* components of the red cells from the *R. grylio* adult corresponded to the faster and slower moving electrophoretic bands, respectively. When present in the cells of the adult, the 10*S* to 11*S* component is eluted with the band of 7.0*S* material. With respect to relative electrophoretic mobility, the slower (2.7*S*) tadpole component migrates at about the same rate as the faster (4.3*S*) frog component.

Amino acid analyses were made on the globins from the best available preparations of tadpole and frog hemoglobins. For the tadpole, analyses were obtained on two pooled lysates which had been centrifuged at 20,000*g* and one pooled sample of electrophoretically purified hemoglobin with comparable results. For the frog, amino acid data are averaged from analyses of the supernatant solution from the centrifugation at 20,000*g* of the washed, lysed red blood cells of three adults. The frog hemoglobin analyses thus include the 4.3*S*, 7.0*S*, and any 10*S* to 11*S* hemoglobins and any other component present in these lysates. Other protein components present are believed to be negligible. The globins were precipitated with a mixture of HCl and acetone, and hydrolyzed by refluxing with 6*N* HCl for 18 hours. Amino acid analyses expressed as residues per 68,000*g* by the Moore-Stein technique (*8*) for tadpole and frog were, respectively: arginine 18, 26; lysine 30, 34; histidine 29, 41; aspartic acid 53, 39; glutamic acid 44, 36; methionine 2, 5; and ½ cystine 0 to 1, 7 to 8. There was a significant increase in dibasic amino acids and a decrease in dicarboxylic amino acids in the transition of tadpole to frog. Also very striking is the increase of half-cystine residues in general agreement with the observations of Riggs (*5*). The changes in amino acid composition are in accord with the experimentally observed differences in rates of migration of these hemoglobins on both starch and paper (see Table 1, properties g, h, and k). It is evident that there is an extensive alteration in amino acid composition of hemoglobin chains during metamorphosis.

Spectrophotometric studies confirmed the absence of any differences in the visible region of the spectrum (*4*). Frog red blood cell lysates resisted methemoglobin formation less readily than did lysates from tadpole cells under identical conditions of storage. A large increase in absorption at 540 mμ compared to 570 mμ and the appearance of the 625 mμ peak characteristic of methemoglobin was observed. The ultraviolet spectrum shows a decrease in the intensity of the tryptophan band at about 289 to 291 mμ during metamorphosis accompanied by a shift to longer wave length characteristic of fetal to adult hemoglobins (*9*).

The now numerous differences in tadpole and frog hemoglobins are summarized in Table 1. Our data would indicate there are at least two principal hemoglobins in the adult *R. grylio* and one in the tadpole. In these experiments the 7.0*S* component does not appear to be interconvertible with the 4.3*S* fraction as evidenced by separate sedimentation experiments with varying protein concentration and increasing ionic strength. The sedimentation patterns for adult *R. grylio* and *R. catesbeiana* are the same whether observed one hour or five days after bleeding, in contrast to adult *X. laevis* samples. Furthermore, the individual components isolated electrophoretically have never given evidence of dimerization or splitting to form the component removed by electrophoresis even after storage for more than 30 days at 5°C. Since there are two or more hemoglobins, this poses some interesting questions regarding their biosynthesis; for example, whether the 7.0*S* hemoglobin, which presumably is an octamer, contains any peptide chains in common with any of the chains of the 4.3*S* tetramers (*10*).

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17 December 1962

Geothermal Brine Well: Mile-Deep Drill Hole May Tap Ore-Bearing Magmatic Water and Rocks Undergoing Metamorphism

Abstract. *A deep geothermal well in California has tapped a very saline brine extraordinarily high in heavy metals and other rare elements; copper and silver are precipitated during brine production. Preliminary evidence suggests that the brine may be pure magmatic water and an active ore-forming solution. Metamorphism of relatively young rocks may also be occurring within accessible depths.*

A geothermal well has been drilled recently in Southern California into a geologic environment that can only be described in spectacular terms. The well was drilled for geothermal power near Niland, close to the Salton Sea in the Imperial Valley, during the winter of 1961–62. It is 5232 feet deep (*1*) and is the deepest well in the world today in the high-temperature hot spring areas. In the lower half of the hole, temperatures are too high to measure with available equipment, but they are at least 270°C and may even reach 370°C. For comparison, the previous maximum temperature reported for hot spring areas is 295°C, observed at Waiotapu, New Zealand, in a 3000-foot drill hole (*2*).

The well taps a very saline brine which has an unusually high potassium content, and perhaps the highest lithium and heavy-metal content known for natural waters. During a production test, the brine deposited in discharge pipes material astonishingly high in silver, copper, and some other scarce elements normally concentrated in ore deposits. Considerable evidence favors the geologically fascinating possibility that this brine is man's first sample of an "active" ore solution of the type that probably formed many of the world's economic concentrations of ore metals in the geologic past. Moreover, this brine may originate at greater depths as a water-rich fluid residue from crystallization in the magma chamber that also supplied the recent rhyolite and obsidian volcanoes of the area. If this is so, the brine is an undiluted magmatic water that can be sampled and studied in detail for the first time.

Equally fascinating is the possibility that temperatures in the lower part of the hole are so high that transformation of young sedimentary rocks into metamorphic rocks is taking place within depths accessible for scientific study. These metamorphic processes are considered to occur at "normal" earth temperatures only at depths below 25,000 to 30,000 feet, beyond present limits for direct study.

The Salton Sea is on the northern extension of the downwarped or downfaulted trough of the Gulf of California. The southernmost recognized branches of the great San Andreas fault of California extend into the area. The general geology of the area has been mapped by Dibblee (*3*); a geophysical study by Kovak and others (*4*) extends up from the south just to the geothermal area. Both reports indicate great structural depression of the trough in the last 10 or 20 million years. An estimated 10 to 20 thousand feet of relatively young sedimentary rocks lie on rocks of pre-Tertiary age, as confirmed in part by oil-test holes up to 12,000 feet deep. Gravity data indicate a local gravity high for the thermal area. This gravity high could be explained by upfaulting of a sliver of relatively heavy pre-Tertiary rocks between branches of the San Andreas fault, but it is perhaps equally well explained by local transformation of young light rocks into heavier rocks. For such changes there is normally a decrease in pore space and a decrease in water content, and new minerals are formed in response to high temperature or pressure; chemical changes other than change in water content may also occur.

Dibblee (*3*) has mapped a northeast-striking line of pumiceous rhyolite and obsidian domes of Quaternary age that lie in and near the geothermal area at the southern end of the Salton Sea, but the northeastern dome—Mullet Island—is not shown on Dibblee's map. The domes, as well as nearby hot springs, mud volcanoes, and shallow wells drilled for CO_2, have been described briefly by others (*5*).

The chemical composition of this extraordinary brine is known quantitatively for only a few components but estimates of the order of magnitude of the concentrations have been made for many other components. Some serious analytical problems are already apparent, and others are expected. A sample of the deep brine was collected from a 3000-gallon water-steam separator of the test system at the end of the 3-month production test. The sample was collected carefully in an attempt to obtain a sample representative of nonerupted brine at depth; the valves were closed on the separator while the proper proportions of brine and high-pressure steam were maintained, and the mixture was then cooled and the steam condensed. Some gas remained as a vapor phase, so the original composition could not be duplicated exactly.

Analyses of the gases (*6*) show 80 to 93 percent (by volume) of CO_2, methane, and other gases; H_2S, of special interest, was reported to be 0.35 percent in a sample collected 1 June 1962, but was not detected in samples collected 4 July and 8 August.

A partial analysis of the water sample (in parts per million by weight) includes (*6*): Na, 54,000; K, 23,800; Li, 321; Ca, 40,000; total halides as Cl, 184,000; evaporated residue (180°C), 332,000; specific gravity at 20°C, 1.262. Semiquantitative spectrographic analysis (*6*) of the evaporated residue indicates the following concentrations, computed in parts per million of the original water: Fe, 3000; Mn, 1000; Ag, 2; B, 500; Ba, 200; Cr, 0.5; Cu, 20; Ni, 2; Pb, 100; Sr, 2000; and Zn, 500. Each figure given is intended only as an indication of the order of magnitude of these concentrations. Many are far higher than reported concentrations in other natural waters (excepting acid mine waters).

This brine, as identified by its major components, is an NaCaCl or NaCaKCl type.

The water of most spring systems associated with volcanism is dominantly of surface origin; when rocks are fractured and permeability permits, the water circulates deeply and is heated by conduction in the high heat-flow environment. Additional heat and perhaps a few percent of magmatic water with dissolved substances are supplied near the base of circulation, and the hot mixture rises in the core of a huge convection system, with little loss in temperature until pressures near the surface are low enough for the water to boil. Thus the typical system has a very high rate of temperature increase from the surface downward for the upper few hundred to a thousand feet or more. The depth of the zone of boiling depends on the temperature of the rising water (*7*). At some depth and temperature characteristic of each spring system, temperatures tend to level off downward, with little further increase at greater explored depths. The Niland system, however, probably has little physical movement of water except perhaps from a magma chamber upward into the brine reservoir where it has presumably displaced water of lower density that formerly occupied the available pore spaces; original ground temperatures before the drilling seem to have been controlled primarily by rock conduction and have shown a nearly straight-line increase with depth.

Pressures within the system are about 25 percent higher than hydrostatic pressures would be for pure water having the same temperature distribution at similar depth (*5*, *8*); normal dilute meteoric water cannot circulate downward against such pressures. In addition, extremely high salinity and high concentrations of elements such as potassium, lithium, and the heavy metals are very unlikely to occur in a dynamic convection system that requires a large supply of scarce elements. For these reasons, and in contrast to most thermal spring systems, we consider seriously only certain kinds of water of deep origin to explain the brine in the Niland system.

The chemical characteristics of different kinds of saline water of deep origin, as presently understood, have been reviewed recently (*9*). The deep

Niland brine is not clearly any one of these previously recognized types. Present limited evidence, namely the very high brine temperature and the unusually high content of potassium, lithium, and other rare elements, suggests a magmatic type not previously recognized with certainty in hot spring areas. This type presumably is so saline and heavy, and so low in volatile components other than H_2O that it ordinarily remains deep within each volcanic system and rarely if ever appears at the surface in high concentration in hot springs. If such a magmatic water does exist, it is similar in its major components, sodium, calcium, and chloride, to the dominant type of very saline connate (fossil) brine of the earth's oilfields of pre-Tertiary age (*9*). But the Niland water differs greatly from these connate waters: the content of potassium and lithium is extraordinarily high, and there is a virtual absence of sulfate. Marine and nonmarine salt deposits can also develop end-stage brines high in potassium and somewhat high in lithium, but these types are normally very high in magnesium and sulfate and low in calcium and heavy metals. The concentrations of cesium, rubidium, bromide, iodide, the heavy metals, and the isotopes of hydrogen and oxygen are of particular interest. These components and the ratio of each to its geochemically most closely related major element (such as Cs/Na and Br/Cl) are becoming very useful in distinguishing waters of different origins (*9*).

If the brine is of magmatic origin and is rising upward into porous rocks and displacing less-dense water of some other origin, a density-stratified interface probably exists at some unknown height above the first casing perforations at 4900 feet; the brine reservoir is probably the local source of heat in the area. Temperatures should increase with depth toward this source of heat but they will then either attain a maximum or will increase less rapidly with increasing depth below the brine interface, depending upon the details of the water circulation within the brine reservoir. On the other hand, if the brine is one of the several nonmagmatic types also being considered, it is being heated entirely from below by thermal conduction, presumably from the magma chamber that was the source of the rhyolite and obsidian domes of the area. For any of these nonmagmatic origins, temperatures probably continue to rise as depth increases through the brine reservoir, although not by a straight-line relationship if thermal conductivities of the rocks differ by very much.

Table 1. Semiquantitative spectrographic analysis of dark deposit in pipes from brine of the deep well (*6*). Results are reported in percentage to the nearest number in the series 1, 0.7, 0.5, 0.3, 0.2, 0.15, and 0.1, and so forth, which represents approximate midpoints of group data on a geometric scale. The assigned group for semiquantitative results includes the quantitative value about 30 percent of the time. The following elements were below the limits of detection: Au, Cd, Ce, Hf, Hg, La, Li, Mo, Nd, P, Pt, Pa, Re, Sc, Ta, Te, Th, Tl, U, W, Y, Zn, Zr.

Element	Percentage	Element	Percentage	Element	Percentage
Si	Major	Ag	2	Ga	0.02
Al	0.7	As	0.15	Ge	0.001
Fe	7	B	0.15	Ni	0.0001
Mg	0.015	Ba	0.015	Pb	0.02
Ca	0.7	Be	0.07	Sb	0.3
Na	1	Bi	0.005	Sn	0.0007
K	1	Co	0.0001	Sr	0.007
Ti	0.0015	Cr	0.0002	V	0.0005
Mn	0.5	Cu	~20*	Yb	0.0002

* This exceptionally high copper content, determined by 1000× dilution, has been confirmed by x-ray fluorescence by W. W. Brannock, who also determined by the same method that the sulfur content was approximately 8 percent.

Of significance also in ascertaining the origin of the water is the nature of dark material deposited from the brine during the 3-month production test. The total quantity of the deposit precipitated in the 275-foot-long horizontal discharge pipe from the well was not measured, but it was so thick at the discharge end that cleaning was required at 1-month intervals (*10*). A rough calculation indicates that 5 to 8 tons were precipitated during the 3 months.

A fire assay of the deposit (*6*), reported a silver content of 381 ounces per ton, or nearly 1.2 percent, and a gold content of 0.11 ounce per ton. A semiquantitative spectrographic analysis of a piece of deposit collected about 100 feet from the discharge end of the pipe is shown in Table 1. The sample from the discharge end has an almost equally high content of heavy metals, and the thin deposit from the well has an even higher content. Natural waters have never before been observed to precipitate such high concentrations of silver and copper; other notable concentrations of elements that are rare or widely dispersed in ordinary rocks are arsenic, boron, beryllium, bismuth, gallium, lead, and antimony. Calculations indicate that 1 to 3 ppm of copper and 0.1 to 0.3 ppm of silver were precipitated from the water to form the pipe deposits. These quantities are in the order of 10 percent of original concentrations indicated by spectrographic analysis for the whole brine.

A "whole-rock" x-ray diffraction analysis of the pipe deposit shows chiefly amorphous material with a high iron background. Most of the low x-ray peaks in the record are very close to those of bornite, a copper-iron sulfide abundant in many copper deposits. Several other peaks have not yet been identified.

The mineral assemblages of rocks, when buried to great depths and heated up to earth temperatures normal for such depths, change to new mineral assemblages called metamorphic rocks. All such rocks that geologists have studied in the past were formed ten million years ago, or more, and at great depths in the earth. Where they are now exposed at and near the earth's surface, extensive uplift and erosion of the original overlying cover has occurred to reveal them. Evidence for the begin-

Table 2. Summary of characteristics of drill core from geothermal wells at Niland.

Approximate depth (ft)	Bulk specific gravity	Minerals present*
4477	2.47	Chlorite, K-feldspar, K-mica, quartz, albite†
4484	2.53	K-feldspar, quartz, chlorite, K-mica, albite†
4662‡	2.52	Quartz, K-feldspar, chlorite, albite, pyrite§
4917	3.18	Epidote, quartz, some feldspar or unknown or both, pyrite‖
4923	2.62	Quartz, chlorite, albite, epidote, pyrite

* In approximate order of decreasing abundance, as determined by whole-rock x-ray diffractometer, and by microscope inspection of thin section. † Epidote and pyrite in veinlets. ‡ From Sportsman No. 1 well of Joseph I. O'Neill and associates, about ¼ mile ESE of the deep well (Imperial Irrigation District No. 1 well) and drill to depth of 4729 feet. § Veinlets of quartz and pyrite without epidote. ‖ Epidote constitutes 60 percent or more of the rock.

ning stages of active metamorphism has been looked for in oil-test wells that are drilled 20,000 feet and more below the surface where "normal" temperatures are in the order of 200°C; however, such evidence has not yet been found. Recent conclusions (*11*) are that "low-grade" metamorphic rocks, with minerals such as chlorite, epidote, and albite, first form normally at depths in the order of 25,000 to 30,000 feet, where temperatures are probably near 250°C.

Five specimens of drill core have been studied in some detail, and the data are summarized in Table 2. All five specimens were originally shale or siltstone, but they now contain minerals characteristic of the greenschist or chlorite grade of metamorphism. The pre-Tertiary basement of the Salton Sea Basin is considered (*3, 4*) to be 10,000 to 20,000 feet below the surface throughout most of the structural trench, and relatively young rocks of Pliocene age dominate the upper 5000 to 10000 feet. If this general picture is correct, the low-grade metamorphic rocks of the drill core must be either old basement rocks that have been upfaulted locally as a sliver between branches of the San Andreas fault, or they are rocks of relatively young Tertiary age that are now being metamorphosed because of high temperatures at these lesser depths.

Some geologists will be of the opinion that mineral changes in this environment should be called "hydrothermal alteration" (commonly produced by the action of ore-depositing waters) rather than "metamorphism." Hydrothermal alteration is normally characterized by new hydrous minerals, and by a decrease in specific gravity of the altered rocks. Metamorphism, on the other hand, normally consists of the formation of new mineral assemblages stable at higher temperatures and pressures than former assemblages; specific gravities usually increase with metamorphism, and water content decreases. In this sense the deep Niland rocks are metamorphic, even though the brines may have brought about some net chemical change.

The age and origin of the metamorphic rocks of the drill core are not determinable with certainty from the present limited data, but several lines of evidence favor the theory of active metamorphism of relatively young rocks.

The data of Table 2 suggest that the grade of metamorphism is increasing as the depth increases within the short interval from 4477 to 4923 feet more rapidly than might be expected for normal old metamorphic rocks. Epidote was found only in veinlets in the two pieces of drill core nearest the surface, but it is abundant in the lower core as a replacement for other silicate minerals. The specific gravity of the drill core in general increases rather rapidly with increased depth, as geologists might expect from a localized rapid downward increase in grade of metamorphism. For comparison elsewhere in the same structural trough (*4*), the drill core from 0 to 4000 feet in depth has an average bulk specific gravity of 2.37; 4000 to 8000 feet, 2.44; and 8000 to 12,000 feet, 2.47. Probably the most significant point in favor of active metamorphism, however, is the fact that wherever bedding is discernible in the five core specimens, it was essentially horizontal, as evidenced by relations to the originally vertical sides of the drill core. In contrast to this, old metamorphic rocks usually have been upfaulted and tilted extensively, and original bedding is only horizontal by coincidence.

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11 January 1963

Low Malignancy of Rous Sarcoma Cells as Evidenced by Poor Transplantability in Turkeys

Abstract. *Homologous and isologous transfers of Rous sarcoma cells in turkeys indicate that growth of the implanted cells contributes little, if at all, to the formation of these neoplasms. Infection of normal host cells by virus appears to be, at least in this species, the major factor in the induction and progressive growth of Rous sarcomas.*

It is well known that Rous sarcoma can be produced in chickens by implantation of tumor cells or injection of cell-free filtrates of the tumor tissue. Tumor production by cell transfer could be the result of either malignant growth of the implanted cells themselves or infection and growth of host cells initiated by virus released from the implanted cells, or a combination of both. There is evidence that in chickens proliferation of the implanted cells does occur in certain instances (*1*). However, preliminary data obtained in our laboratory (*2*) clearly indicated that in turkeys virus was much more important than cells for the induction and progressive growth of these tumors.

In the studies we report now (*3*), large numbers of intact and viable tumor cells, obtained by trypsinization of virus-induced turkey sarcomas, were implanted into the wing web of large numbers of turkeys. These experiments were conducted as follows: 7-day-old Beltsville white turkeys of both sexes were injected subcutaneously in the left wing web with 0.2-ml amounts of standard Rous sarcoma virus that had been prepared from chicken tumor tissue (*4*). Tumors were produced by injection of 10^4 to 10^5 pock-forming