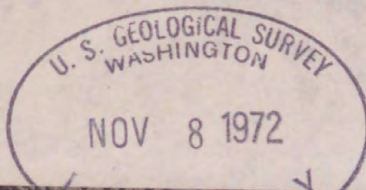


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[Report, open file.]

AN HYPOTHESIS OF THE CHEMICAL ENVIRONMENT
OF THE RAND GOLDFIELD, SOUTH AFRICA

By W. B. ^{W.B.} Myers, 197-



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By W. B. Myers

Gold- and uranium-bearing conglomerates in South Africa, Russia, and Canada are of about the same early Proterozoic age--2,500 m.y.--according to radiometric dating (Roscoe, 1969; Tugarinov and Grinenko, 1969; Pisemskii and others, 1969). Similarity of environmental factors, rather than accidents of provenance, may have been responsible for the contemporaneity of these deposits. I suggest here that the chemical stability of gold in all these deposits was due to very low oxygen pressure of the early atmosphere. (That the uraninite, now unstable, in these deposits owes its presence to low oxygen pressure has been suggested by Liebenberg, 1955; Holland, 1962; and Hiemstra, 1968.)

The high oxygen pressure (0.2 atm.) of the earth's present atmosphere is very largely due to biologic photosynthesis. The only other possibly significant mechanism for producing oxygen is the photodissociation of water vapor in the upper atmosphere by solar ultraviolet radiation, but the evidence indicates that this mechanism is ineffective. Even Brinkmann (1969), whose calculations suggest a much higher level of photochemical production than has been previously accepted (Berkner and Marshall, 1964), concluded from geologic evidence that previous to 2,000 m.y. ago, the process was vitiated by an atmospheric sink of reduced gases. Although there is some disagreement as to the species and amounts of reduced gases in the early atmosphere (Rubey, 1951; Holland, 1962; Abelson, 1966), it is generally agreed that volcanism assured the presence of H_2S .

Garrels and Christ (1965, p. 219) have shown that even in low concentrations H_2S would convert magnetite to pyrite at the low Eh conditions of the inferred Rand atmosphere. Magnetite and other iron oxides thus would have been converted to pyrite during weathering, erosion, and transportation.

The association in the Rand Goldfield of both detrital and oolitic pyrite in shallow-water crossbedded coarse clastic sediments, and the general absence of pyrite from graded-bed silts and shaly rocks, contrast sharply with the occurrence of pyrite in younger rocks formed under foul-bottom conditions. This ancient association of oolitic sulfide and shallow-water aerated sediments suggests that an anoxygenic environment controlled biologic photosynthesis.

The living colored sulfur bacteria are photosynthesizers, viable only in a specific environment, that are capable of reducing carbon dioxide to carbohydrate under anaerobic conditions by the intracellular oxidation of hydrogen sulfide to sulfur or sulfate. These are among the most primitive living photosynthetic organisms and can manufacture all the

elements for cell building without organic substrates. Because they are both photosynthetic and anaerobic, only very restricted ecologic niches are open to them in the modern oxygenated environment. The colored sulfur bacteria can, however, develop beneath a layer of pond algae, because bacterial chlorophyll has a different absorption spectrum from that of green plants. The bacteria seek the closest approach to the surface that allows anaerobic conditions, but they can exist at low light levels and are locally found to depths of several hundred meters (Kondrat'eva, 1965, p. 5-15).

The sulfate-reducing bacteria are more familiar to geologists than are the photosynthetic sulfur bacteria. These sulfur manipulators are chemisynthetic and oxidize preexisting carbohydrate with oxygen acquired by the anaerobic reduction of inorganic sulfate.

The photosynthetic sulfur bacteria and the sulfate-reducing bacteria were first cultured symbiotically in the laboratory in 1888. Many investigators of poorly oxygenated water bodies have described a sulfur cycle based largely on these two bacterial groups (Kondrat'eva, 1965, p. 17-19). The natural assemblage appears to be responsible for the biologic production of sulfur in some small Libyan lakes.

Such an anaerobic symbiosis could have held full sway in the essentially anoxygenic Witwatersrand environment. In the shallow waters of the neritic zone, the high input of solar energy could have held the total sulfur concentration well above the levels of the surrounding benthonic regions. Some of the excess sulfur would be in bacterially mediated pyrite, and the remainder would be in a mixture of H_2S and a lesser amount of sulfate. (Such sulfate is produced within the cells of the colored sulfur bacteria, and is not the result of combination of sulfur with free atmospheric oxygen.) The presence of the sulfate raises the Eh of the waters.

Where pyrite is concentrated, however, the Eh of the environment is lowered in comparison with that of an area deficient in sulfide. Uraninite, which is not stable in the modern oxygenated (high Eh) environment, would be protected by the concentration of pyrite. Gold is stable in the presence of oxygen over the entire field of stability of water but may be easily complexed, notably by halogens and cyanides, in the presence of oxygen or an equivalent high Eh (Pourbaix, 1966, p. 403). Thus gold also would be protected by the lower Eh of pyrite-rich areas. The strong correlation between pyrite and the content of gold and uranium in Rand ores has long been recognized.

The isotopic composition of the sulfur of Witwatersrand pyrite is unfractionated (Jensen and Dechow, 1965; Hoefs and others, 1968). Similar results have been obtained from the pyritic conglomerates of the Krivoi Rog and Kursk Series in the U.S.S.R. (Tugarinov and Grinenko, 1969). No fractionation is to be expected if pyrite mediated by bacterial symbiosis is added to detrital pyrite of magmatic origin and detrital pyrite resulting from sulfidization of magnetite and other iron oxides, for the biogenic

trade-off of sulfur species cancels out any single-stage fractionation. Sulfur in sulfided magnetite originally should not have been fractionated either, as that material resulted from abiotic action of atmospheric H_2S .

The very fine median grain sizes of hydraulically equivalent heavy minerals in the Rand reefs is in contrast to most modern placers. The most comparable modern deposits seem to be the beach and offshore placers of the Oregon Coast of the United States (Clifton and others, 1967). The range of sizes in these ancient and modern deposits is generally similar--save for the virtually total lack of gold particles smaller than 40 microns in the Oregon sands. In the Rand reefs, by contrast, about 40 of each hundred particles are smaller than the smallest preserved in the oxygenated placers.

The rate of solution of small particles is strongly influenced by particle size because the ratio of area to volume is inversely proportional to the mean radius of the particle. Thus particles 40 microns in diameter lose material by solution 3 times faster per unit of mass than do 120 micron particles; 4 micron particles do so 30 times faster. If an approach to a steady state is assumed, with new detrital metal particles being added to the accumulation as old metal particles are made smaller by solution, the smallest particle present in appreciable numbers is a factor of the solution rate. Liebenberg (1955, p. 163-164) states that detrital gold particles are found in the Rand bankets down to a minimum size of 2 x 3 microns; and that 5-micron detrital specks are common. If we accept 40 and 4 microns as reasonable minima for the Oregon and Rand particles, respectively, then an effective solution rate in the Oregon deposits is ten times that in the most productive Rand reefs.

I regard this lowered rate of solution of the ancient placers as the explanation for their remarkable grade. The Oregon deposits reach a grade of a little more than \$.10/ton. The 76-year average for all ore mined on the Central Rand is 0.255 oz/ton, worth just less than \$9--about two orders of magnitude richer than the modern deposits.

References cited

- Abelson, P. H., 1966, Chemical events on the primitive earth: Natl. Acad. Sci. Proc., v. 55, no. 6, p. 1365-1372.
- Berkner, L. V., and Marshall, L. C., 1964, The history of growth of oxygen in the earth's atmosphere, p. 102-126 in Brancazio, P. J., and Cameron, A. G. W., eds., The origin and evolution of atmospheres and oceans--Goddard Inst. for Space Studies Conf., 1963, Proc.: John Wiley & Sons, Inc., 314 p.
- Brinkmann, R. T., 1969, Dissociation of water vapor and evolution of oxygen in the terrestrial atmosphere: Jour. Geophys. Research, v. 74, no. 23, p. 5355-5368.
- Clifton, H. E., Hubert, Arthur, and Phillips, R. L., 1967, Marine sediment sample preparation for analysis for low concentrations of detrital gold: U.S. Geol. Survey Circ. 545, 11 p.
- Garrels, R. M., and Christ, C. L., 1965, Solutions, minerals, and equilibria: New York, Harper and Row, 450 p.
- Hiemstra, S. A., 1968, The geochemistry of the uraniferous conglomerate of the Dominion Reefs Mine, Klerksdorp area: Geol. Soc. South Africa Trans. and Proc., v. 71, pt. 1, p. 67-100.
- Hoefs, J., Nielsen, R., and Schidlowski, M., 1968, Sulfur isotope abundances in pyrite from the Witwatersrand conglomerates: Econ. Geology, v. 163, no. 8, p. 975-977.
- Holland, H. D., 1962, Model for the evolution of the earth's atmosphere, p. 447-477 in Engel, A. E. J., James, H. L., and Leonard, B. F., eds., Petrologic studies--A volume in honor of A. F. Buddington: New York, Geol. Soc. America, 660 p.
- Jensen, M. L., and Dechow, E., 1965, Bearing of sulfur isotopes on the origin of Southern African ore deposits, in Abstracts for 1964: Geol. Soc. America Spec. Paper 82, p. 101.
- Kondrat'eva, E. N., 1965, Photosynthetic bacteria [English translation]: London, Oldbourne Press, 243 p.
- Liebenberg, W. R., 1955, The occurrence and origin of gold and radioactive minerals in the Witwatersrand system, the Dominion reef, the Ventersdorp contact reef and the Black reef [with discussion]: Geol. Soc. South Africa Trans. and Proc., v. 58, p. 101-254.
- Pisemskii, G. V., Ganzha, L. M., and Bolotova, N. Ya., 1969, Preliminary results of the study of the gold content of Precambrian conglomerates in the region of Krivoi Rog and the Kursk magnetic anomaly, in Smirnov, V. I., ed., Problema metallonostnosti drevnikh konglomeratov na territorii SSSR [in Russian]: Moskva, Izdat. Nauka, 187 p.

- Pourbaix, Marcel, ed., 1966, Atlas of electrochemical equilibria in aqueous solutions [1st English ed.]: Pergamon Press, 644 p.
- Roscoe, S. M., 1969, Huronian rocks and uraniferous conglomerates: Canada Geol. Survey Paper 68-40, 205 p.
- Rubey, W. W., 1951, Geologic history of sea water--An attempt to state the problem: Geol. Soc. America Bull., v. 62, no. 9, p. 1111-1147.
- Tugarinov, A. I., and Grinenko, V. A., 1969, Conditions of sedimentation of lower Proterozoic formations from data on the variation of isotopic composition of sulfur sulfides, p. 205-216 in Khitarov, N. I., ed., Problems of geochemistry [English translation]: Jerusalem, Israel Program for Sci. Translations, 754 p.
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