LATERIZATION AS A POSSIBLE CONTRIBUTOR TO GOLD PLACERS

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Twenty four years of observation have gradually suggested to the author that gold, in small amounts but evenly distributed throughout ultrabasic rocks, may be chemically dissolved and re-precipitated in possible commercial placer concentrations by the normal process of laterization.

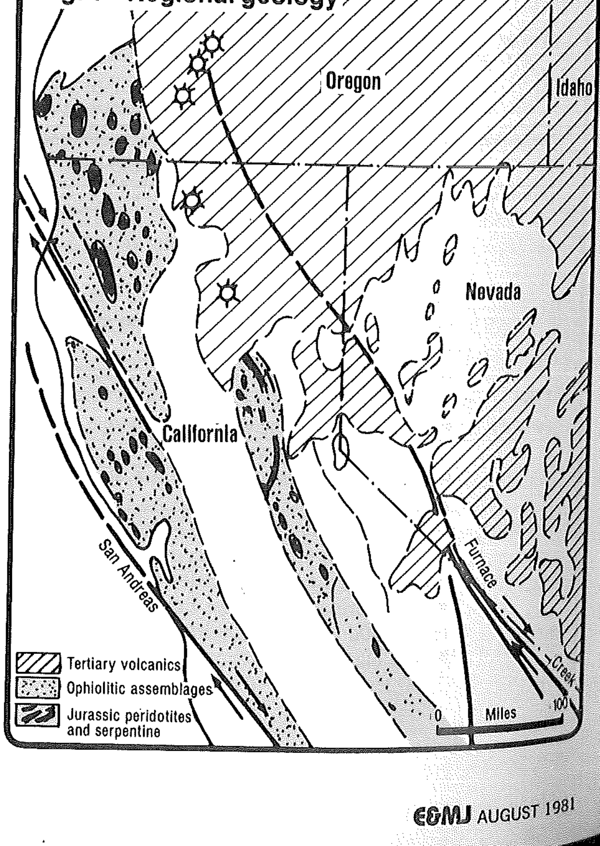
The arrival at such a premise has been accompanied by some troubled thinking dating back to 1955, after a detailed study of a French Guiana gold placer. At that time, it was concluded that the only possible source of the placer gold was the thick, red, lateritic soil cut by the stream channel. Of particular interest was the fact that some of the gold in the channel obviously had been re-precipitated from solution.

If this premise is true, it may account for some of the gold deposits in the higher Tertiary channels of California's Mother Lode country and on the west slope of the Sierra Nevada. Furthermore, this premise may explain the occurrence of extremely large nuggets of exceptional fineness, which early-day placer miners would not accept as the product of eroded vein structure. It might also partially account for the scattered placer gold in southwestern Oregon and the abundance of gold in the channels and tributaries of the Klamath and Trinity Rivers of northwestern California. Assuming the soundness of this premise, a key is suggested to exploration for undiscovered, large-yardage, low-grade deposits minable by open-pit methods in many parts of the world.

In 1955, prevailing concepts of gold mineralization only recognized the fact that many major gold placer areas are centered on or flank regions of laterized ultrabasic rocks. The long-held commandment that gold is insoluble under normal conditions closed the door on the idea that it might be concentrated by solution and re-precipitation—although this idea was postulated by some of the early participants in the California gold rush. By 1972, however, contributions to the literature were providing the chemistry needed to permit questioning of gold's presumed insolubility.

Such a suggestion does not imply that all lateritic deposits contain unrecognized secondary concentrations of gold. Much less does it suggest that the many successful nickel-silicate mines, as a group, have been overlooking by-product

Fig. 1—Regional geology



*The author first studied laterites at Riddle, Ore., in 1941 while participating in the discovery and exploration of the Eight Dollar Mountain deposits. In 1942 and 1952, he examined the main nickeliferous laterites that continue south through California's Del Norte County. He has also worked in French Guiana, the California Mother Lode area, Siskiyou and Trinity counties in California, and Costa Rica.

gold values. In fact, study of many excellent papers on worldwide nickel operations has revealed no references to gold—not in traces measurable in parts per million, not in raw ore or concentrates, and not in the refined product. The suggestion does permit consideration of the possibility that nickel-cobalt and gold deposits separately but not in combination may have a common lateritic origin.

Lateritic deposits result from the alteration of rock masses. The conditions that produce such alteration include a tropical climate, to promote steady chemical disintegration; a regionally flat surface and similarly flat water table, to assure little movement of solutions after they enter the zone of saturation; and long time intervals, to allow the chemical action to penetrate great thicknesses of rock. Laterization of acid, light-colored rocks has produced bauxite deposits in the Caribbean, along the northern coast of South America, in the southeastern US, and in Costa Rica and Australia, among other locations. Laterization of peridotites, dunites, gabbros, and other ultrabasic rocks, has fostered the nickel silicate deposits of New Caledonia, Cuba, the Philippines, Colombia, Guatemala, Venezuela, Brazil, Oregon, northwestern California, and other regions.

ENIGMA OF CALIFORNIA GOLD

From the earliest days of the California gold rush, San Francisco journals indicated evidence of interest in the actual origin of the state's placer gold, especially in the drift mines that followed old Tertiary channels. THE MINING AND SCIENTIFIC PRESS carried letters from miners and discussions by leaders in the scientific community that questioned accepted theories. An article by a Dr. Landsweert (1869) is representative of the general tone of this debate. He wrote: "Every one concurs in the belief that alluvial gold has been derived at some time or other from lodes; but seeing that the largest piece of gold ever found in the matrix is insignificant when compared with the nuggets that have sometimes been found in the alluvium, it has been a difficult matter to reconcile belief with experience."

Dr. Landseert described a number of experiments in which very dilute solutions of gold chloride and a carbonaceous material used as a "decomposing" agent were mixed to precipitate films of gold on centers of pyrite, iron, copper, antimony, galena, and other metals and minerals. Using brown iron ore, gold was deposited as a fine metallic powder.

Dr. Landsweert concluded: "The occurrence of larger nuggets in gravel deposits than have been found in quartz ledges, with the fact that alluvial gold almost universally has a higher standard of fineness, would seem to imply a different origin for the two." He also quoted a contemporary, a Professor Bischoff, who added fuel to the fire by saying: ". . . the very marked difference between much of the alluvial gold and vein gold indicates that the alluvial had some other origin and was transferred from the reefs to the drifts by some means other than denudation; and when we consider that the nuggety gold consists of nearly the heaviest known matter, offering but a small surface of attack when compared to the other constituents of the veins, it appears strange that they should be found at a great distance from any known reefs, as nearly all the large nuggets have been."

Such discussion naturally drew opposition from those who defended the gospel of denudation and mechanical transport of gold from source rock.

In further support of the solution hypothesis, Professor Joseph Le Conte (1871) offered the following: "Will sulphate of iron dissolve gold? We must remember in this connection the difference between the operations of the chemist and those of nature. The chemist calls a substance insoluble if it

Fig. 2—Areas of peneplanation

Fig. 3—Gold producing areas

is not dissolved to any considerable extent in a limited space of time. But nature has infinite ages of geologic time to work. Hence, a substance dissolved only in part by the chemist may be entirely dissolved by nature. . . ."

Describing the pocket deposits of eastern Trinity county and western Shasta county, California, O. M. Hershey (1910), observed: "The gold lies in a thin, flat sheet . . . it is in the form of coarse and fine grains that have a peculiar smooth and rounded surface, quite *unlike* the fine gold in quartz veins . . . I believe that some of the finely divided gold (detritus from base-metal veins with very low gold values) passes into solution in the zone of oxidation and is leached out by the descending meteoric waters . . . and some may be deposited in cracks in the rock to form the so-called 'pocket' seams.

"This certainly is secondary concentration by meteoric waters, circulating near the surface, though it is not secondary enrichment in the sense ordinarily meant."

Hershey remained undecided as to whether deposition occurs in the zone of oxidation or just below it, but he concluded: ". . . (the gold) is transported in solution in ordinary cold meteoric waters, circulating within several hundred feet of the surface. . . ."

F. W. Clarke (1908) pointed out that the natural solvents of gold appear to be numerous. Gold is held in solution by potassium silicate, and it is perceptibly soluble in a 10% sodium carbonate solution or a mixture of sodium silicate and bicarbonate. Solutions of alkaline sulphides have been found to be effective solvents. Hydrogen sulphide attacks gold perceptibly. *All* of these solvents occur in natural waters.

Clarke referred to an experiment by T. A. Rickard in which a sample of Cripple Creek ore, containing manganic oxides, was treated with a solution of ferric sulphate, sodium chloride, and a little sulphuric acid. All of the gold was dissolved. A fragment of black carbonaceous shale was immersed in the solution, and the gold was precipitated.

The experiment illustrated the ease with which gold is redeposited from its solutions. Organic matter of almost any kind will precipitate gold, and such matter is rarely, if ever, absent from the soil. Gold, therefore, although it may enter into solution, is not likely to be carried far before it is precipitated. Gold is thrown out of solution by ferrous salts, other metals, and many sulphides, as well as ordinary soil.

RECENT LABORATORY EFFORTS

Recent studies, although not designed to support the premise of laterization as a source contributing to gold in placers, *do* support the solubility of gold in nature. Cloke and Kelly (1964) confirmed earlier work by Emmons (1917) and Krauskoph (1951) that indicated that acid chloride solutions in the presence of a strong oxidizing agent produce conditions favorable for the solution of gold. A solution of H_2SO_4 and NaCl exposed to pyrolusite and goethite on a gold plate, respectively, dissolved gold in appreciable amounts in both cases. Cloke and Kelly emphasized the fact that the only inorganic acid commonly present in the supergene environment is H_2SO_4, which is formed through the oxidation of sulphides remaining in the gossan.

Concerning supergene transport, Coke and Kelly reported that "the actual process of movement of gold is envisioned to involve repeated solution and deposition," and they concluded, "The preceeding evidence supports the conclusion that acid chloride solutions, together with iron and manganese oxides can provide supergene transport of gold."

With reference to goethite, Hotz (1964) listed limonite, goethite, and maghemite as constituents of the brick red surficial soil of Oregon's laterites, with these minerals characterized by shot-like granules. Maghemite is a magnetic anhydrous ferric oxide.

With reference to maghemite, Coveney (1972), reporting on the localization of high-grade gold ores in California's Oriental mine deduced that hydrogen gas accompanying magnetite at a serpentine contact was the reducing agent. Precise work indicated that the H_2 was not in the serpentine but in the bi-occurrences of magnetite.

Rucklidge (1972) concurs with White (1968) in the belief that chlorine is a significant element in environments where metals are being redistributed and deposited. He further states that high chlorine in serpentines comes from partial serpentinization. He concludes that "The influence of chlorine-bearing fluids on the movement and redistribution of metals from *ultramafic* rocks is a tantalizing subject."

OREGON AND CALIFORNIA PLACERS

The central valley of California is a simple subduction zone trough flanked on the west by the Klamath Mountains and the Coast Ranges and on the east by the Sierra Nevada foothills. It extends from San Joaquin in the south through the Sacramento Valley until it is terminated in the north by a covering of Miocene-Pliocene Cascade volcanics. The rock units in the Klamath Mountains and Coast Ranges consist of a melange of Triassic ophiolites, Jurassic basic intrusives and serpentines, and lower Cretaceous Franciscan metasediments and metavolcanics. The Sierra Nevada foothills are made up of Triassic ophiolitic assemblages (ocean plate) and Jurassic ultrabasic intrusives and serpentines. (The regional geology, peneplain patterns, and gold areas are illustrated in Figs. 1, 2, and 3.)

Both the Klamath Mountains/Coast Ranges and the Sierra Nevada foothills have gold placer histories and future potential—but only where they are coincident with Cretaceous peneplanation. In southwestern Oregon, this peneplanation begins in the Riddle area, continues south to the north bank of the Klamath River, and proceeds thence southeasterly through the Weaverville-Hayfork districts (Fig. 2). Projecting this trend across the central valley to the Sierra Nevada permits a correlation of similar materials and conditions on both flanks of the valley. The elevations in Fig. 2 are not too diagnostic, since they reflect the results of tectonic growth starting in the Cretaceous. Descriptions by Diller refer to a Klamath (upper) peneplain and a Sherwood (lower) peneplain. At Riddle, Ore., the upper ore flat at 3,500 ft elevation and the lower ore flat at 2,500 ft elevation may correspond with these designations.

From Riddle south to the California line, other Sherwood remnants at about 2,500 ft elevation can be identified at Red Flat, Eight Dollar Mountain, Free and Easy, Woodcock Mountain, and Rough and Ready Mountain. All of these areas are nickel prospects. Riddle is the site of the only producing nickel mine in the US, which is operated by The Hanna Mining Co. Recognition of the significance of peneplanation first occurred early in this century and was discussed by Diller (1910), Hershey (1910), and Lindgren (1911).

Fig. 3 outlines gold-producing areas and illustrates their promising coincidence with peneplaned areas. In southern Oregon, the Rogue River and its tributaries have been worked extensively for placer gold, as have the Waldo-Jacksonville and Illinois River drainage areas south of the Rogue and the area south of Eight Dollar Mountain near Kirby. The Oregon State Geological Survey's Bulletin 61

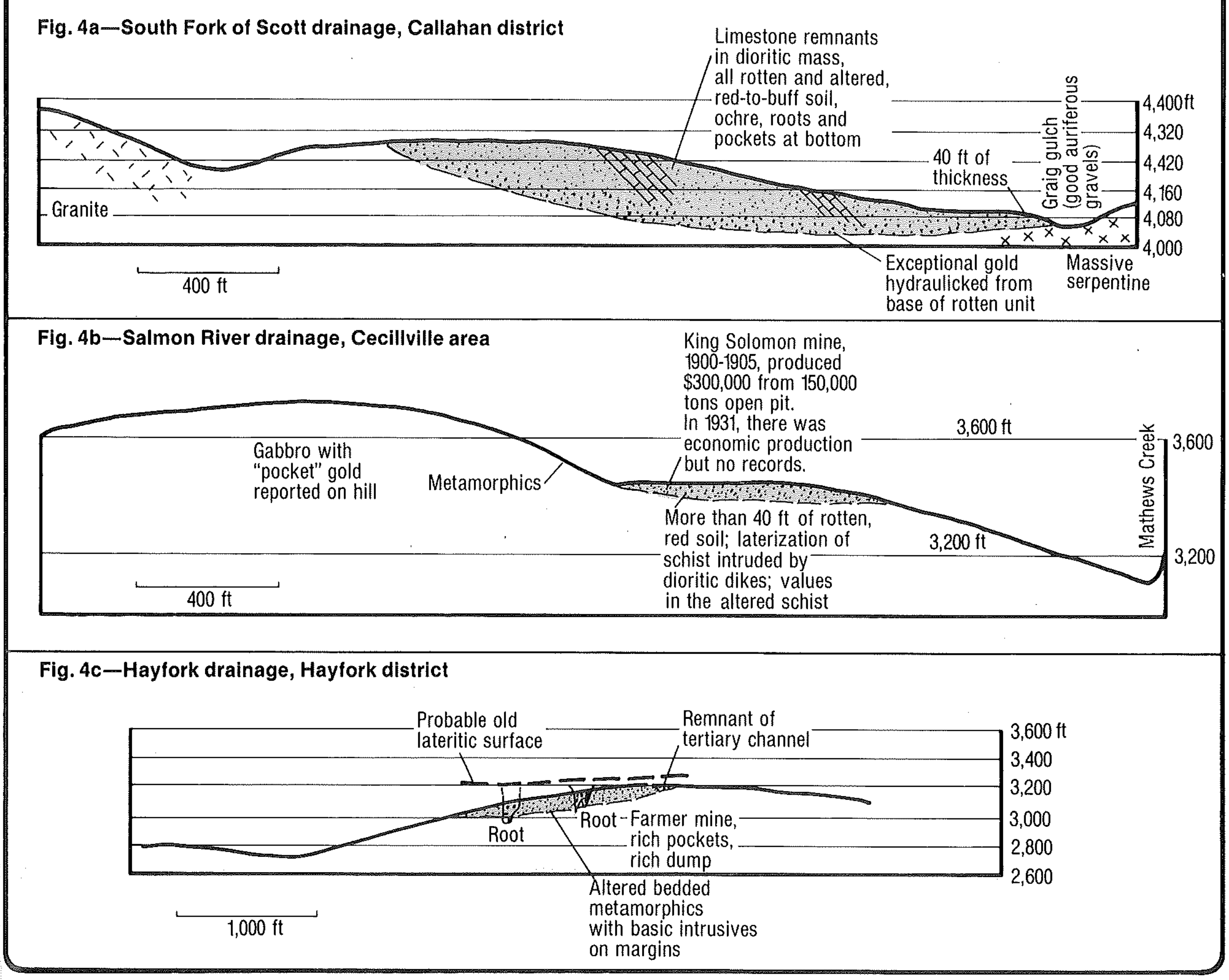


Fig. 4—Free gold associated with lateralization in Trinity and Siskiyou counties, California

provides good historical and geological detail about these districts. An association with an ultrabasic complex is suggestive.

SOUTHERN KALAMATH

Jurassic ultrabasics, laterized peneplain remnants, and exceptional placer gold deposits such as those found in southwestern Oregon also occur farther south in the Siskiyou-Trinity region of California. Peneplain remnants in this area include Pine Flat, 2,500 ft; Low Plateau, 2,600 ft; High Plateau, 3,500 ft; Little Rattlesnake, 3,200 ft; Rattlesnake, 3,600 ft; and Red Mountain, 4,000 ft, as well as four others that conform to requirements but have not been mapped. These four are in Del Norte county, north of the Klamath river and close to the coast.

Continuing southeasterly to the Weaverville area, other peneplain remnants include the King Solomon mine, 3,300 ft; the Crawford anomaly, 4,200 ft; and the Dog Paw laterite, 4,200 ft. There are also three such remnants in the Cecilville area on the Salmon River drainage and another at Wildcat Creek west of Callahan. All of these peneplain remnants are auriferous. The King Solomon and Wildcat Creek properties produced economically from rotten, red-to-buff, lateritic soil deposits. Neither reflects a vein source nor orthodox gravel characteristics.

Of special interest is section A of Fig. 4. The position of a thick layer of exceptional gold at serpentine bedrock and beneath barren (leached?), rotten, heavily oxidized diorite is considered very significant. Section B of the same figure shows laterized diorites and schists with some gold concentration at King Solomon's mine flanked by gabbro with scattered "pocket" gold. Section C shows the Hayfork district, with pockets or "roots" of gold beneath a remnant of stripped-away laterite.

Study of various records of gold production in the Klamath Mountain province in California indicates a total production of 11,369,000 oz, of which 87% can be attributed to placer mining.

MOTHER LODE AREA

The existence of peneplanation in the Sierra Nevada foothills was the subject of some debate in the early 1900s. Lindgren, in the classic "Tertiary Gravels of the Sierra Nevada of California" (1911), questioned such a thesis, attributing the regional flatness to level lava flows that conceal a pre-Tertiary surface. He qualified this view to some extent by noting that east of the depression between Forest Hill and North Columbia, the terrain rises to an

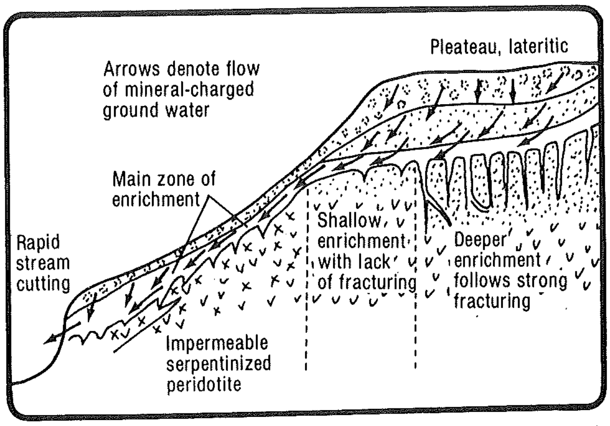


Fig 5—This composite shows how a lateritic nickel orebody can be enriched by migratory solution and indicates clearly the extent to which enrichment is guided by fractures in the underlying bedrock.

undulating plateau that extends over a considerable space at an elevation of 3,000 to 5,000 ft. (This area contains sufficient nickel silicate to have justified recent exploration.)

Others, including Diller (1910) and Hershey (1911), supported the peneplanation thesis, as do some researchers today. In a personal study, the author constructed profiles from Magalia to Forest Hill that indicates two terraces, at 4,300 and 3,300 ft. The width of the terraces is 15 mi, and the distance covered is 80 mi. There is also a suggestion of a third terrace at 2,500 ft. Direct observation in scattered areas reveals a surface of heavy red soil and an irregular contact between overlying laterization and underlying basic rocks, with some serpentinization. In many respects, the area is similar to laterized areas in southwestern Oregon and northwestern California.

Sierra Nevada placer gold, won from Tertiary channels and existing streams, accounted for about 66,817,000 oz of California's total gold production of 106,276,163 oz through 1970, 63% of the total. Further review of records indicates that these placers accounted for 74% of production in the Sierra Nevada province.

W. B. Clark (1979) notes that Eocene channels are the most extensive and productive in the Sierra and that they originated in Cretaceous time, when streams flowed across a subdued topography into a shallow Cretaceous sea west of today's Sierra. The Eocene climate is generally thought to have been sub-tropical, permitting deep weathering of rock.

These older Eocene channels consist of boulders of intrusive and metamorphic rocks, as well as white milky quartz. In some cases, there are "greenstone" gravels near bedrock that have "yielded significant quantities of gold." In all cases, the highest proportion of gold occurs at or near bedrock in the oldest deposits.

Gold particles range from flour size to coarse nuggets weighing more than 100 oz. Fineness of the gold is exceptional, ranging from 850 to 950.

Thus, the Sierra Nevada portion of the Oregon-Klamath-Sierra trend repeats certain basic conditions. The gold-producing areas occupy certain Triassic-Jurassic trends of ultrabasic intrusives but only where overlain by Cretaceous peneplanation that was followed by laterization of the ultrabasic masses. The fineness (purity) of gold is exceptionally high. Production in all cases was in part from well-developed vein structures in the Jurassic basic units and in part from placers, which represent 60-87% of an area's total production. The few isolated observations in the Klamath area of placer concentrations tied to laterization cannot be repeated for the Sierra, possibly because of insufficient work.

PRE-CAMBRIAN FRENCH GUIANA

In 1955, the author undertook studies of placer deposits in French Guiana, where, except for a thin strip of Quaternary shales and sands on the coast and some sandstones and conglomerates of Cretaceous age in a few streams, all of the rock is of pre-Cambrian age. An upper complex of schists and conglomerates is designated the Orapu series, and a lower complex of schists and quartzite is designated the Paramaka series. These rocks, with unclassified quartzites and amphibolites at the very base of the column, all rest on underlying granite. Before Orapu time, first diorites, granodiorites, and gabbros, and later granites invaded the Paramaka rock sequence.

Quartz veins that are slightly auriferous have been mined without economic success at St. Elie, Adieu Vat, and Bief. Veins also occur in the Sauvenier-Haute Mana area, on the Orapu and Comte Rivers, between the Orapu and Approuague Rivers, in the Arouany Basin, on Lezard Creek, and elsewhere. The gold is thought to derive from the diorites, granodiorites, and gabbros, which carry disseminations of pyrite and chalcopyrite and probably minor gold with the sulphides.

The French Guiana portion of the Guiana shield has been a positive area since at least pre-Cambrian time, exposed to a tropical environment on a flat terrain—the required conditions for laterization. There is evidence for at least two periods of vast peneplanation and "telescoping" of thick rock masses by chemical disintegration and reorganization. Brown ferruginous soil of varying thickness occurs as thin layers atop terrace remnants and covers the slopes away from the terraces. The ferruginous soils grade abruptly into massive secondary limonite and minor hematite at the contact with partially altered bedrock.

Where soils have been removed by erosion, massive iron oxide caps the upper elevations. Massive limonite with large voids in the matrix is known as "box-work" iron.

Streams flow through valley fill that consists of transported boulders of lateritic iron underlain by 5-15 ft of thick laterite-derived clay, which, in turn, caps several feet of gold-bearing sand and gravel.

Guianans had worked the few feet of auriferous gravels in current drainages, as well as so-called "hillside" placers that occur as detrital deposits on the flanks of streams well above drainage and in the laterite itself. These workers claimed they were getting better values, with less effort, from the "hillside" placers than from the present stream.

Supporting the possibility of gold being soluble in nature under the proper conditions, the author observed clusters of recent fine, clean sand grains wired together with fibrous, crystalline gold. Gold was also observed coating rounded pellets of iron oxide, in the voids of iron oxide, and as angular quartz pebbles. Fineness approached 950. No gold was noted in pure vein quartz.

Geologists working in French Guiana have noted that placer deposits occur where drainages cross areas of diorite, granodiorite, and gabbro. Choubert (pre-1955) states, "Our observations allow us to affirm that placers and veins (of gold) are concentrated exclusively in areas of dioritic intrusives, old lava flows, or both," and "gold-bearing laterites have been recognized in all of the Guianas."

Braceville (1946) reports, "Gold placers are found within or close to ridges of metamorphic rocks . . . they are more often than not situated in lateritic areas and the laterite itself often contains workable values . . . concentrations of the deposits by alluvial agencies has resulted in the production of extensive workable deposits in small gullies, streams, and on hillsides.

"The bulk of the gold produced in British Guiana has probably been obtained from alluvial deposits not more than 6 ft deep, in which the gravel layer is usually 1 ft thick and contains values of about $2 per yard, or about 30¢ per yard overall value . . ."

SUPPORT FOR SOLUTION PREMISE?

There are differences between the French Guinana and California gold provinces. In French Guiana, laterization occurred in ultrabasic gabbros, granodiorites, and diorites, which are dissimilar to the laterized peridotites, dunites, and their serpentinized equivalents of the Oregon and California gold provinces. However, all of these areas seem to share the possibility that laterization of very low-grade gold in basic to ultrabasic rocks provided a source for economic placer gold deposits. Such concentration may, at least in part, have been a matter of solution and re-precipitation aided by mechanical concentration. ■

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