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APPLICATION OF GOLD FINENESS TO THE SEARCH FOR ORE.

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INTRODUCTION.

It has been fairly firmly established (Fisher, N.H., 1945) that the fineness of the gold in any ore deposit varies with the depth from the surface at which the deposit was formed and as a corollary to this, that it is dependent upon the temperature and pressure at the time of deposition. This relationship is such that, under certain conditions, the gold fineness, taken into consideration with other recognised criteria, furnishes a very sensitive and reliable guide to the relative temperature of ore formation, at least within the epithermal and the upper part of the mesothermal range.

DEFINITION OF FINENESS.

The fineness of gold is calculated in parts per thousand and refers to the proportion of gold present in the naturally occurring metal in the lode, which is actually a gold-silver alloy, containing usually about 10 parts per thousand of base metal and up to 500 parts per thousand of silver. A clear distinction should be made between fineness and gold-silver ratio. The latter refers to the total gold and silver in the lode as determined by assay and is usually expressed as the ratio Au:Ag. Only in deposits where other silver-bearing minerals are entirely absent, which occurs comparatively rarely, can the gold-silver ratio be used as a measure of gold fineness and, in many cases, the two have no relationship. For instance, in the Edie Creek area in New Guinea, the lodes formed under shallow epithermal conditions all carry gold 500 to 550 fine, although the gold-silver ratio ranges from 1:100 to 1:1, in places in adjacent lodes.

DETERMINATION OF GOLD FINENESS.

The fineness of lode gold can be determined only after it has been separated from all other minerals. Amalgamation recovers gold fairly cleanly - unless native silver is present - and the fineness of amalgam bullion is generally a reliable indication of the correct fineness of the gold. If the use of plates is involved, the bullion may be adulterated, but the effect of any copper, or other metal, that may have been introduced can be cancelled by assuming that the gold and silver should add up to about 990 fine, or by ignoring the base metal content altogether, which varies little in naturally-occurring gold, and in calculating for comparison purposes all fineness figures to the basis Au+Ag = 1,000.

The composition of bullion obtained from cyanidation is generally intermediate between the true gold fineness and the total gold-silver proportion as determined by assay of mine or mill-head samples. Cyanide solution dissolves other silver-bearing minerals and the fineness of the resulting bullion is thereby lowered. Consequently, the fineness of cyanide bullion rarely corresponds to the true gold fineness and is useless for diagnostic purposes, although it is a common fallacy to refer to the fineness of cyanide bullion as the fine-
/the ness of/gold. If no silver other than that contained in the gold is present, its fineness may approximate the true figure, and if only a little extraneous silver is present, or if all the silver present is contained in minerals that are soluble in cyanide solution, the bullion fineness gives a useful indication of the gold-silver ratio and its variations, which may in itself be quite an important factor in the detailed study of mineralization within a lode or in an ore-bearing district. The inferences

drawn from this, however, should be considered separately from those drawn from variations in gold fineness.

The usual source of gold fineness figures is from bullion obtained by amalgamation or from alluvial gold. The unreliability of these figures and the inability to correlate bullion returns with any particular section or level within the mine have constituted severe handicaps in the attempt to study the full implications of gold fineness variation. The only satisfactory method of obtaining full information is to collect at various horizons samples large enough for a clean physical separation, by grinding and amalgamation or other means, of sufficient gold to run a bullion assay. This, unfortunately, is seldom done, hence the paucity of information on variations in gold fineness within gold lodes. If more mining companies would arrange to have fineness determinations made on large representative samples from each level, so that a mass of reliable information on gold fineness variation could be built up, it is likely that this information could be used to indicate significant variations in the character of the mineralisation and give a much better understanding of the conditions of ore formation and the factors controlling gold deposition. A plea is made here to gold mine operators, particularly where average gold fineness is not high, to have sufficient work of this kind done to enable a reasonable picture of the gold fineness distribution to be plotted on a longitudinal section of the lode, and not to continue to disregard what may be a valuable aid to ore-finding.

VARIATIONS IN GOLD FINENESS SUBSEQUENT TO DEPOSITION.

1. Alluvial Gold.

The fineness of the alluvial gold obtained on any field is a measure of the fineness of the gold shed from the reef outcrop, but does not necessarily correspond exactly to the fineness of the gold as deposited in the ore. In many, if not most, cases, the outcrop gold is relatively enriched in gold by the removal of silver in solution, and in addition the possibility exists that fine gold may have been redeposited from solution near the present outcrop. The removal of silver from gold particles takes place only to a limited depth from the surface of the particles or from the surface of the individual grains of which the particles are composed and has been referred to as surface refining action. This process may take place within the lode or after the gold has been removed from the outcrop by erosion and has started its migration towards the alluvial deposits. The wellknown increase in fineness of alluvial gold downstream with distance from its source is a direct result of this surface refining action - not so much because more silver is dissolved as it travels along, but because the size of the particles transported naturally decreases with distance, and those with smaller grain size have had a relatively higher proportion of their bulk exposed to differential solution of silver. Thus, it has been calculated (Fisher, M.S., 1935), that nuggets or flakes of alluvial gold of thickness 1mm. or more, made up of grains 0.1 mm. in diameter, might be enriched 10 parts per 1,000 if the original fineness were 600, and smaller particles one tenth that size, just small enough to be referred to as dust, might be enriched by 30 parts per 1,000, while extremely fine dust might be enriched 100 parts per 1,000 or even more.

2. Within the Lode.

Changes in gold fineness with/in the lode subsequent to deposition are most marked in those cases where conditions are favourable for secondary enrichment, to which these changes are naturally related. In many epithermal deposits where manganese is abundant and solutions can circulate fairly freely, the effects of secondary enrichment, particularly in tropical climates, are well developed. First, the silver is leached from the near-surface gold and redeposited at or near ground water level. For instance, at Day Dawn, Edie Creek, the silver content of the ore was low near the surface, rose to over 70 oz. per ton near the bottom of the oxidised zone and dropped to 2.5 oz. per ton in the primary ore. This leaves the outcrop relatively enriched in gold of higher fineness than that originally deposited. If the environment is favourable and erosion not too rapid, the gold also is taken into solution and redeposited either at water level, or somewhere between water-level and the surface, according to concentration, available precipitants and other variable factors. Studies of fineness distribution in New Guinea indicate that, where silver is abundant, the gold thus redeposited may not necessarily be of high fineness but may be of similar grade to the original gold, for although ore values almost everywhere drop sharply to unpayable figures in the unoxidised zone, the fineness of the gold immediately above the top of the sulphide zone does not show any significant difference from that elsewhere in the mines.

Under other conditions, where the dissolved silver is first removed entirely in solution before secondary enrichment begins to affect the gold, the re-depositedrgold may be of higher fineness than the original, as shown by the studies of Mackay (1944) in the Lupa Goldfield, Tanganyika.

Generally, secondary enrichment of gold lodes is a slow process and in many cases lags behind erosion, so that the highest grade gold is found at and not far below the outcrop.

Much more detailed study is required to determine more precisely the effects of secondary processes upon gold distribution and upon gold fineness.

RELATION OF GOLD FINENESS TO TYPE OF DEPOSIT.

1. Epithermal type.

Lodes formed under epithermal conditions at shallow depths typically contain gold from about 500 to 700 fine. No genuine case has been found of lode gold with a fineness of less than about 475. In this zone the correspondence between gold fineness and temperature of formation appears to be very close, and the gold fineness furnishes a sensitive measure of the conditions of deposition. Deposits formed in Late Tertiary times under shallow cover carry gold about 500 fine as a rule, while those formed near the bottom of the zone or in what Graton (1933) has called the leptothermal zone - transitional from the epithermal to the mesothermal - contain gold about 700 fine, possibly ranging up to as much as 800. Studies made by R.V. Gaines (personal communication) consequent upon the publication of the writer's original paper in 1945, furnish an illustration of this type of variation. Samples were collected at various horizons in the Timmins Ochali-Berlin mine near Yarumal in the Antioquia region of Colombia, South America. This lode is considered to have been formed near the top of the mesothermal zone. Gold fineness in the primary ore was found to increase downwards from 680 to 760 over a vertical distance of 1300 feet. These figures provide a very satisfactory confirmation of the deductions as to the probable variation in gold fineness at this depth that were drawn from a general study of the subject.

Exceptions to the rule that epithermal deposits carry comparatively low-grade gold occur only in deposits in which silver is conspicuously absent and insufficient silver was present in the ore-bearing solutions to form an alloy appropriate to the environment. As long as sufficient silver is present, even though it is only just sufficient, low-grade gold will be found in epithermal deposits.

If tellurium is present, it will combine with the gold and silver in proportions appropriate to the relative concentrations, so that the gold telluride, calaverite, will be formed in regions like Cripple Creek where little silver is present in the ore, and silver-gold tellurides where silver is abundant. Gold appears to have a greater affinity for tellurium than for silver and will combine with it in preference to silver. If excess gold and silver are present after all the tellurium has been taken into combination as tellurides, they will be deposited as an alloy of fineness typical of the environment e.g. in epithermal deposits such as those of Karacs-Czebe, Transylvania, low fineness gold is formed

MESOTHERMAL AND HYPOTHERMAL DEPOSITS.

Deposits in this zone normally carry gold from 750 to 900 fine, but the fineness may be higher in areas poor in silver. A very common fineness in lodes of the mesothermal zone is 850 to 870.

It is not impossible that under certain special chemical conditions, or in the presence of certain minerals, gold of lower than the typical fineness may be deposited in mesothermal deposits, but such cases, if they exist at all, are rare exceptions.

Deposits of the hypothermal zone always contain gold in excess of 800 fine, no matter how much silver may be present in the ore.

Gold of very high fineness, 990 or more, is generally the result of oxidation under conditions favourable for the complete removal of silver. Mount Morgan, Queensland, and Kalgoorlie, Western Australia, are excellent examples.

APPLICATION OF GOLD FINENESS.

1. Lode Deposits.

Probably the most useful application of fineness of gold in any deposit is its value in diagnosing the conditions under which the lode was formed. The knowledge that the ore minerals were deposited under mesothermal or epithermal conditions may well be the starting point on which detailed study of ore distribution and its sources are to be based especially if by detailed study of the fineness range within the lode, some indication is given as to its probable position within the relevant zone.

The possible behaviour of the lode with increasing depth, or more accurately, at lower horizons referred to the geothermal gradient at the time of mineralisation, may then be postulated on a fairly firm basis. It may be practicable to relate pitch of ore-shoots and the course of channels of mineralisation to variations of fineness.

Similarly, a study of the differences in gold fineness throughout a mineralised district may furnish the key to the magmatic source of the mineralisation and enable a more reliable zoning of the deposits than is possible by any other means. This may lead to a better understanding of the distribution of mineralisation both within individual lodes and throughout a mineralised district and, taken into consideration with structure and other considerations, may furnish an important lead for further prospecting.

Another important use to which a study of the gold fineness distribution can be put is to determine the amount of secondary enrichment that has taken place. In those lodes where a noticeable decrease in grade of ore occurs at or about the base of the zone of oxidation, systematic determination of gold fineness at various depths from the surface down to the sulphide zone should give a definite indication of the amount of secondary enrichment that has taken place, if any, and thereby show whether the drop in ore values can be accounted for wholly or partly by this process, or whether it represents the bottom of a primary ore shoot.

2. Alluvial Deposits.

In an area where more than one grade of gold occurs, the uses to which a knowledge of the gold fineness can be put are indeed manifold. The relative importance as sources of gold of the various areas drained by different streams can be assessed with some accuracy. For instance, on the Morobe Goldfield, the fineness of gold below the junction of the Watut and Bulolo rivers averages about 740, that of the Watut above the junction 825, and that of the Bulolo 665, which shows that approximately 2/5 of the gold below the junction has come down the Watut river, and 3/5 of the gold down the Bulolo. Where allowance is made for the vast quantity of gold that has remained in the extensive alluvial deposits of the Bulolo river above the junction, it is obvious that the Bulolo watershed is much the more important source of the two. Numerous other examples of the use of gold fineness in determining the relative importance of different gold sheds are set out in the writer's paper on the fineness of gold, to which reference has previously been made.

Similarly, sudden changes in the fineness of gold along a stream may indicate the presence of important new sources of gold. On the Morobe field, small local increases in fineness are caused by the addition of high-grade gold (870 fine) from creeks draining areas in which gold is associated with granodiorite. On the other hand, the average fineness of gold in the Bulolo river when it passes the mouth of Koranga Creek, drops from 777 to 658, showing that a major source of low-grade gold has been tapped.

The value to the prospector of the knowledge of the relative importance of the various contributory streams is obvious, as it provides for him an order of preference in his prospecting work.

In an area where the fineness of the gold associated with each type of intrusive has been well established, the value of the gold not only gives the prospector and the geologist a definite lead towards its source, but also indicates its probable geological associations and the type of deposit to be looked for. For instance, from a knowledge of the distribution of the gold in the Waria River area, New Guinea, and of its fineness, it was possible to forecast with some accuracy the main features of the economic geology of that district, the position of the main granitic mass and the type and distribution of various smaller porphyry intrusions.

CONCLUSION.

So little detailed work has yet been done on the manner of gold fineness variation, particularly within individual lodes, on the causes contributing to this variation and on the possible modifying factors, that the applications set out in this paper may be regarded as only a few of the practical uses to which information on gold fineness may eventually be put, when more research has been undertaken and a fuller understanding reached of the processes involved. An opportunity is thereby provided for gold-mining companies to make a very real contribution to the application of scientific methods to prospecting for further ore deposits, and this paper concludes with another plea to operators to determine, record and study the distribution of gold fineness on the properties they control, especially if the fineness is relatively low or variable, and to publish the results of such investigations.

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