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PLACER GOLD IN FINNISH LAPLAND

by
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Approximately 1000 kg of placer gold has been panned in the Ivalojoki and Lemmenjoki districts of Finnish Lapland since 1870. Most of the gold has been panned from glaciofluvial gravels in the valleys, but gold can also frequently be found in till. The placer gold deposits are situated within the southern part of the granulitic bedrock terrain of Lapland, where rocks of igneous and sedimentry origin alternate. These rocks are cut by veins composed of quartz and carbonates, and quartz and hematite. In all likelihood, the placer gold originates from these local veins, as has been suggested earlier. This is shown, for example, by sulphide minerals such as pyrite, pyrrhotite and by bismuth minerals, all of which are typical of gold mineralizations and have been found inside the gold grains by microanalysis. These minerals were obviously leached out from the outer margin of the grains, which are poor in silver, <0.5 % as against 0—47 % in the inner parts. Arsenic and gold are correlative in the veins and in the till as are gold and vein quartz in the till. Gold has become concentrated as a result of preglacial weathering, fluvial and expecially glaciofluvial activities. Graphite, a marked constituent of granulite, seems to act as a gold trap, resulting in moderate enrichment of gold during weathering processes. Unweathered graphite-rich rocks are devoid of gold.

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INTRODUCTION

The history of gold panning in Lapland has been written mainly in the Ivalojoki and Lemmenjoki areas (Fig. 1.). Gold was discovered in autumn 1868 in the Ivalojoki area downstream of the Ritakoski rapids, and the gold rush reached its peak by 1871, when there were 491 registered gold panners. In addition to the main course of the river Ivalojoki (Fig. 2), gold has been discovered in two of its southern tributaries, the rivers Sotajoki and Palsinoja, and also along the tributaries of Tolosjoki and in the headwaters of the Lutto river in the Laanila area (Fig. 3). Gold was found in the bottom sand and river terraces, where it occurs in vertically and horizontally sharply limited strata. It was also encountered in fissures in the bedrock, which have acted as natural riffles.

According to official statistics, a quarter of a million cubic metres of material was panned in the Ivalojoki area in the years 1870—1910, yielding 464 kg of gold. This would mean an average of 1.8 gr/m^3 (Hall 1918).

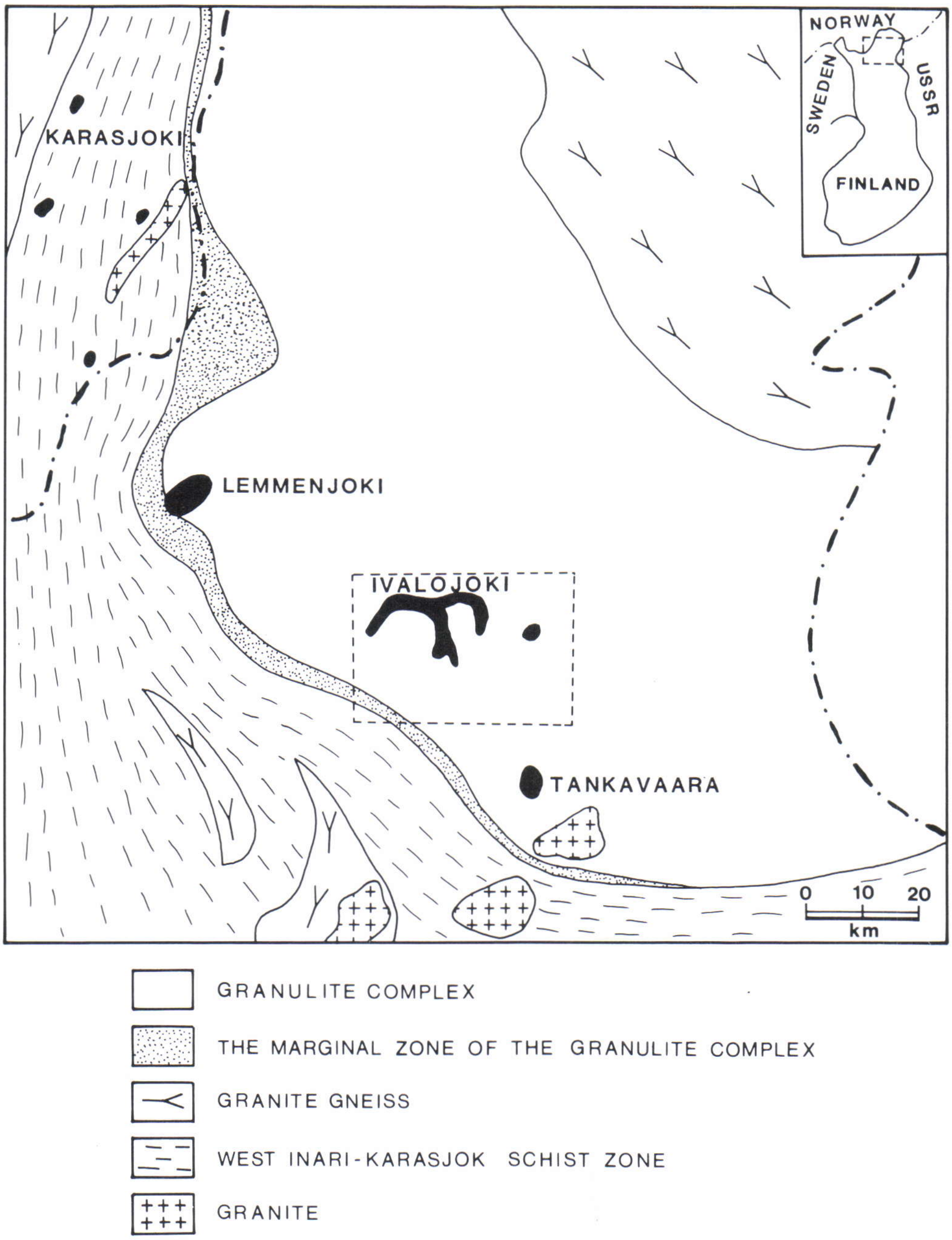

Fig. 1. The placer gold areas of Ivalojoki, Lemmenjoki and Tankavaara shown in relation to the main bedrock units of northern Lapland. The placer gold areas of northern Norway according to Bjørlykke (1966) are also indicated.

The gold of the Lemmenjoki area came to the knowledge of the general public in autumn 1945 and this new gold rush came to a peak in 1949—1951, when more than one hundred miners were working in the area. Gold was found in the valleys of Morgamoja, Ruihtuäytsi, Puskuoja and Jäkälä-äytsi, for example, all tributaries of the river Lemmenjoki, and in the valley of Miessijoki, a tributary of Vaskojoki. These all acted as late-glacial meltwater channels in this elevated fjell area, where most of the placer gold deposits lie between 300 and 450 m a.s.l. Approximately 200 kg of gold has been panned from the poorly sorted gravels of the valley bottoms.

A separate placer gold area is Tankavaara, 30 km south of Laanila, where panning dates back to the 1930's. Geologically it is similar to the Ivalojoki and Lemmenjoki areas, being situated in the southern part of granulitic bedrock of Lapland (Fig. 1.).

By the turn of the century gold prospecting

Fig. 2. The main Ivalojoki valley upstream of Kultala. The bare washed slopes especially on the left side of the figure show the extent of gold panning activities which began in 1870. Photo M. Saarnisto 1982.

had been directed towards the bedrock of the Laanila and Ivalojoki areas. Gold was said to be found in quartz-carbonate veins, which were excavated to a depth of up to 50 metres (Fircks 1906). These veins were also regarded as a source of placer gold. The results of the mining were not promising, however, and some doubts have been expressed regarding the actual gold content of these veins, as no free gold has been seen with the naked eye since then and the later analyses of large samples have given negative results. The status of the veins as a source of placer gold has also been questioned (Stigzelius & Ervamaa 1962).

Attempts have been made to mechanize placer mining, although the greatest efforts, made in the Ivalojoki area in the 1920s, ended in failure. Since the early 1970s the old panning areas have been the scene of a new gold rush, partly because of the rise in the price of gold, but to a great extent also because of the increase in leisure time. Some 200 claims are now effective, and the gold is being concentrated by both conventinal panning and minor-scale mechanized placer mining methods. The annual yield of gold is, however, only between 5 and 10 kg, whereas the total quantity of gold panned in Lapland since 1870 can be estimated at roughly 1000 kg.

The history of gold panning has been described exhaustively in several books and novels, but published scientific articles on the geology of Lapland gold are rare, and only short summaries have been written in English (e.g. Stigzelius 1954). Reports on the geological work undertaken in the gold areas of Lapland are preserved in the archives of the Geological Survey of Finland. One of the oldest geological maps in Finland is the bedrock map of Inari Lapland at a scale of 1 : 800 000, published in 1874, and made by Mauritz Jernström, who participated in the gold studies in the Ivalojoki area.

The present article outlines some of the results of the current work on the geology of gold undertaken by the authors mainly in the Ivalojoki area and to a lesser extent in the Lemmenjoki area (Saarnisto & Tamminen 1985). This research was inspired by the availability of greatly improved, rapid analytical methods, principally the various microanalysis techniques, which allow investigations of the composition of small gold grains and their inclusions.

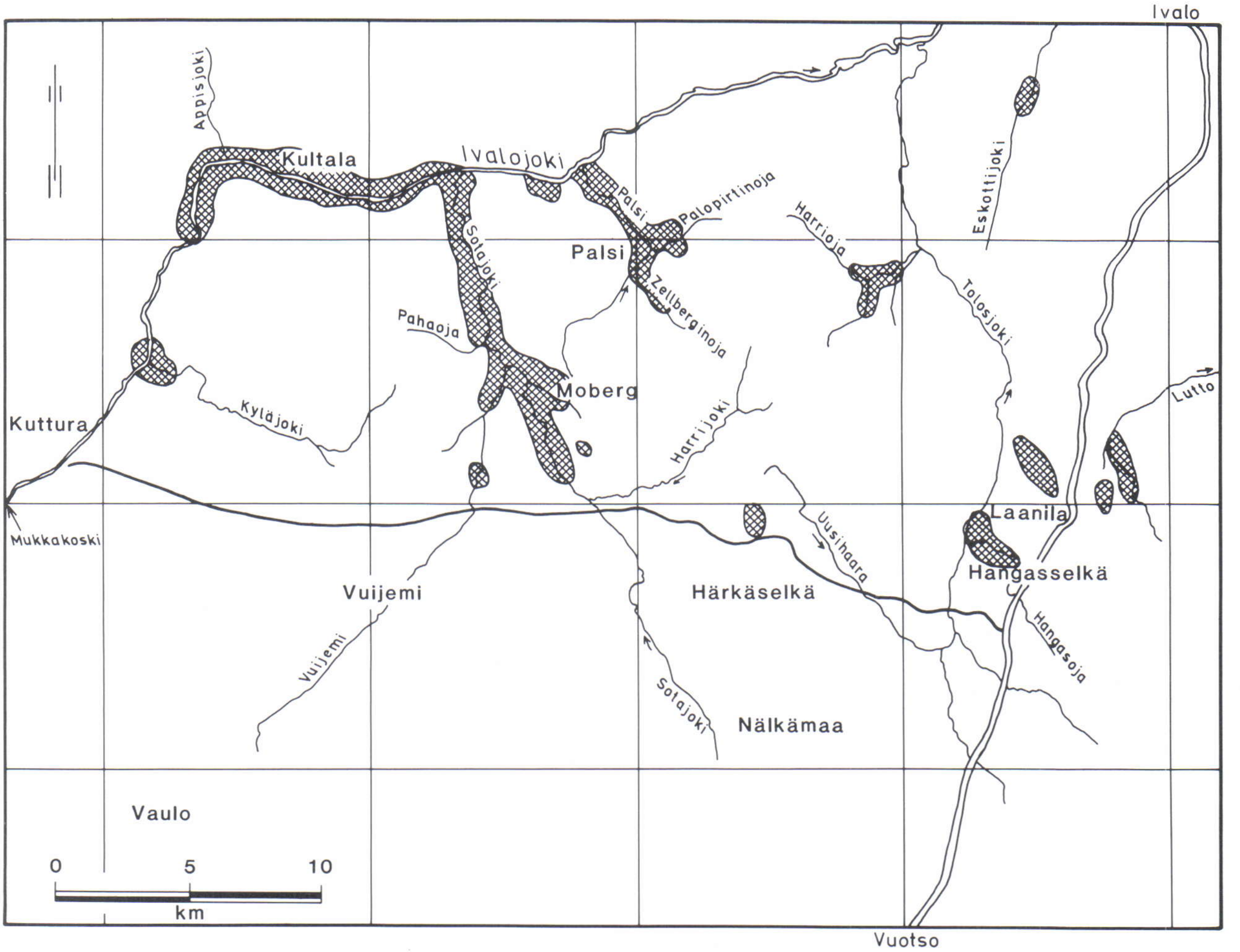

Fig. 3. The old gold panning areas of the Ivalojoki district (shaded) according to Hall (1918). The road leading to Kuttura separates the hilly northern part from the more gently sloping southern area.

TOPOGRAPHY AND GLACIAL DEPOSITS OF THE IVALOJOKI AREA

The bottom of the Ivalojoki valley lies 140—160 m above sea level, whereas the surrounding hill tops reach 400 m. Thus relative heights in the northern part of this area exceed 200 m. In the south the landscape levels out and relative heights are normally less than 50 m.

The bedrock was deeply weathered in preglacial times, a process which can be indirectly dated to the late Tertiary, as the area was probably covered by the sea during early Tertiary times. This is suggested by marine diatoms discovered in secondary positions at several sites in Lapland (Tynni 1982).

The valley topography mainly reflects the tectonic structure of the bedrock. During deglaciation, the river valleys acted as meltwater channels, which has sharpened their morphology. The main Ivalojoki valley gathered meltwater from vast areas in the south, and some small brooks known to be rich placer gold localities, e.g. Moberginoja and Hangasoja, are meltwater channels eroded in surficial loose deposits, principally in till. Similarly, most gold panned in the Lemmenjoki area has been from late-glacial meltwater channels, as mentioned above. Glacial meltwater streams have undoubtedly played an important role in the enrichment of gold. The main Ivalojoki valley is filled with proglacial outwash sediments upstream of Ritakoski, and gravel deposits can similarly be found in the lower courses of Tolosjoki and Sotajoki. Gold has been panned extensively in these deposits in the Sotajoki and Ivalojoki valleys, whereas no workable amounts have been found in the main Tolosjoki valley. These deposits were not investigated in the current work, as identification of their source area was considered more difficult than in till.

The principal direction of transport of the continental ice was towards the north-northeast,

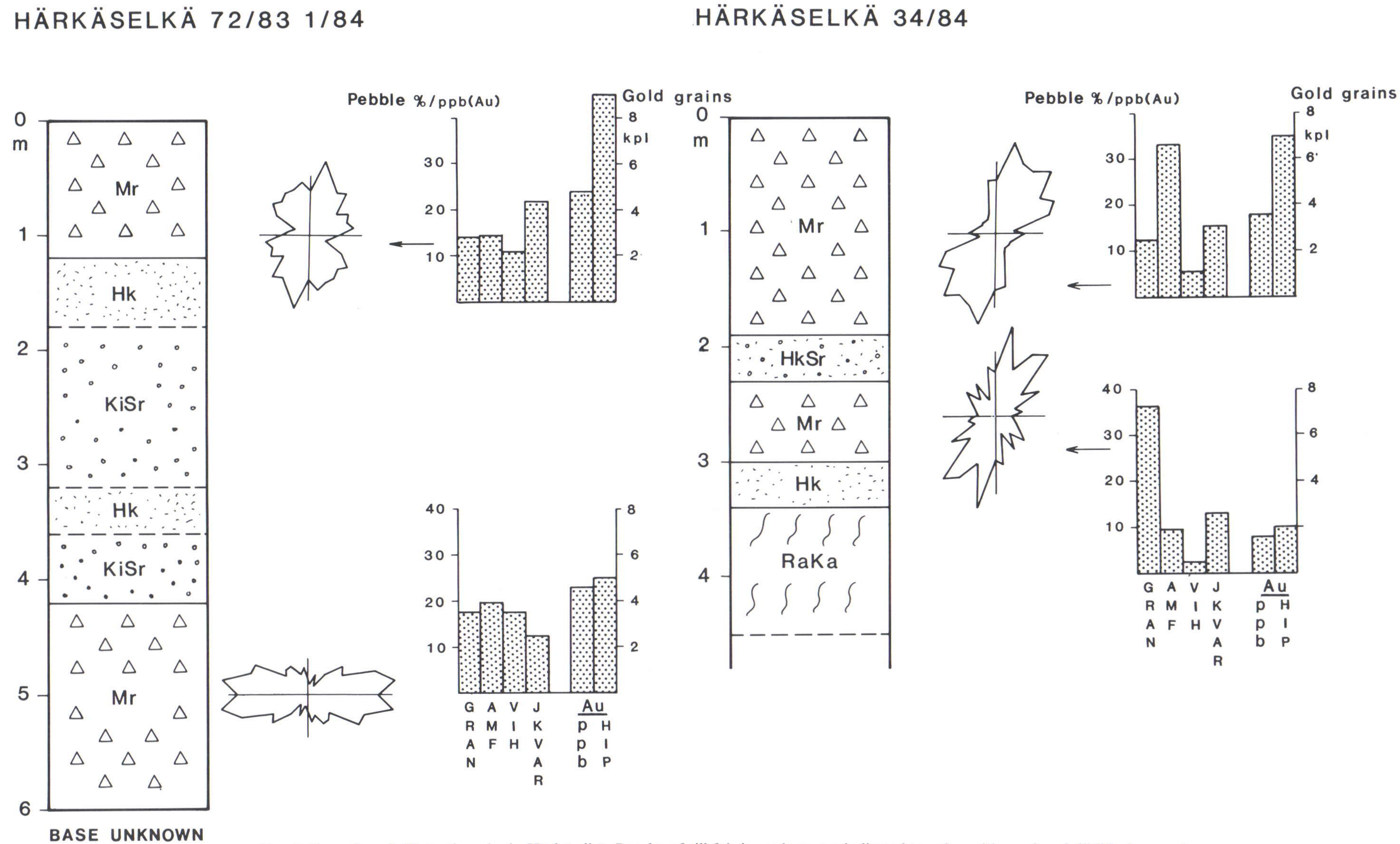

Fig. 4. Examples of till stratigraphy in Härkäselkä. Results of till fabric analyses are indicated together with results of till lithology and gold analyses: ppb = content of trace metals in NAA analysis; number of gold grains in panning per 50 litre-sample is also indicated, GRAN = garnet gneiss, AMF = amphibolite, VIH = greenstone, JKVAR = vein quartz. At site 73/83 (base unknown) two till beds are separated by almost three metres of sorted sand and gravel. The origin of the tills is attributed to two different ice flow stages, whereas at site 34/84 the till layers separated by a thin gravel layer are understood to derive from one and same flow. (Mr = till, Hk = sand, KiSr = pebbly gravel, RaKa = weathered bedrock).

and the glacial meltwater streams similarly ran from south to north. The glacial stratigraphy usually consists of only one till bed, but sorted glaciofluvial material was also found beneath the till at several sites. At two sites another till bed was found underlying this glaciofluvial deposit (Fig. 4).

The pebble lithology of the tills normally indicates very local provenance. Even lithological boundaries could be located fairly accurately with stone counts. Along one survey line running in the direction of ice flow from Vaulo to Palsinoja (Fig. 3) across lithological boundaries, garnet gneiss accounts for some 70 % of the till pebbles within 4 km of its proximal boundary. The source of gold in the bedrock is thus preferentially thought to lie close to its place of discovery in the till. There are some areas, however, where long-distance material is abundant. One of these is Härkäselkä, where the till contains more than 30 % greenstones (chlorite amphibole rocks) in some places (Fig. 4). These rocks were obviously transported a minimum of 15 km from the southern marginal zone of the granulitic terrain. The uppermost till bed is underlain by sorted material, sand and gravel, and therefore the till may contain redeposited glaciofluvial material, which would explain the long transport distance. On the other hand, Härkäselkä is an elevated hill area and could have attracted long-distance englacial debris from the glacier.

GOLD IN GLACIAL DEPOSITS

The occurrence of gold in glacial deposits was investigated from 263 pits dug mainly in till using a mechanical excavator. Observations were made on the glacial stratigraphy, direction of ice transport, till lithology (360 pebble counts) and trace metal content. The maximum excavation depth was normally 4 m, and 155 pits extended to the bedrock, which was often weathered and could easily be penetrated. A 50-litre sample of all the separate beds of till or glaciofluvial material was panned for gold and other heavy minerals. Trace metals, including gold, in fines (<0.063 mm) were analysed by neutron activation analysis (NAA) or atomic absorption spectrophotometry (AAS) in 885 samples.

The number of gold grains in the till seems to be correlative with vein quartz, amphibolites and greenstones, although the correlations are statistically uncertain since the number of gold grains was usually less than 10; the number was considerably higher in sorted sands and gravels. The few data from the Lemmenjoki area suggest that the enrichment of gold due to meltwater action was at least 10 to 20 times observed in till.

In addition to gold, the panned heavy mineral concentrate contains iron oxides, i.e. hematite, magnetite, limonite and ilmenite, together with garnet and small quantities of epidote, monazite, rutile, zircon and occasionally also corundum. No sulphide minerals were detected. Platinoid minerals accompany the gold in small quantities, the most common being sperrylite (Fig. 5) and ferroplatinium. These heavy minerals may give some indication of the origin of the gold, although their concentration is of course mainly dependent on their weight.

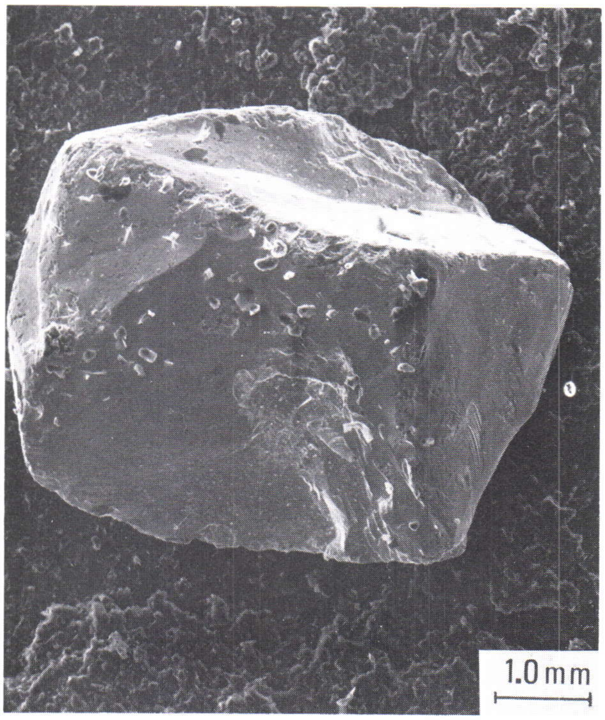

Fig. 5. Sperrylite from the Moberg area. Scanning electron micrograph (SEM).

The average gold content of the till and the till bearing material derived from the weathered bedrock is 7 ppb (NAA method), which is higher than in the unweathered bedrock. The maximum figures are 68 ppb (NAA) and 290

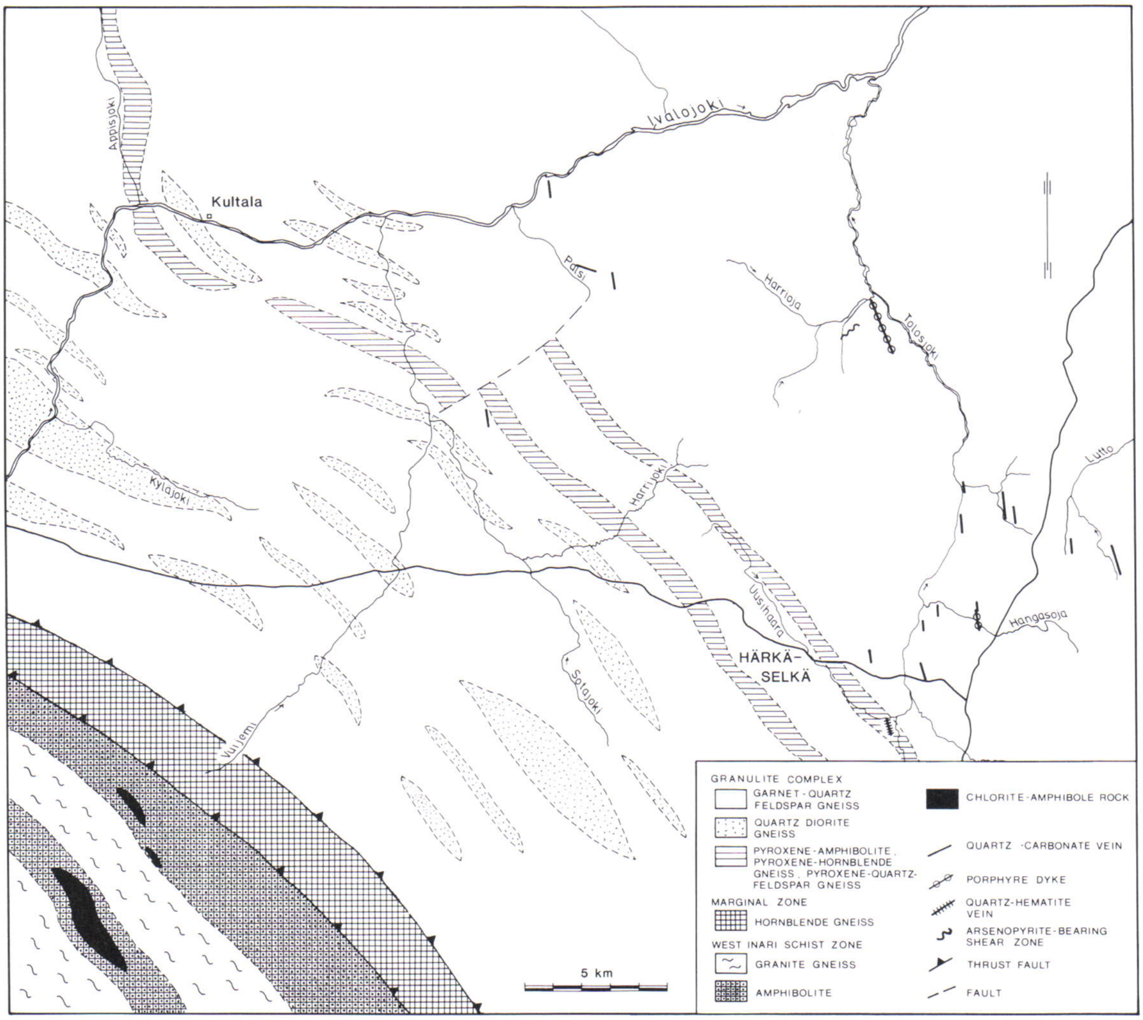

Fig. 6. Main features of the bedrock in the Ivalojoki area.

ppb (AAS). The instrumentally analysed gold in the till does not correlate with the till lithology, except in some subareas, e.g. Härkäselkä, where trace metal gold is correlative with chlorite amphibole rocks and vein quartz. The number of gold grains panned and the instrumentally analysed gold are likewise not correlative, which indicates how differently the methods measure the gold content. These methodological problems have been discussed by several authors, e.g. Clifton *et al.* (1969).

BEDROCK

Regional bedrock mapping was carried out in connection with the current work within the same area as that where the glacial deposits were investigated. Several possible source rocks of placer gold were mapped and sampled in detail. These include minor stratabound graphite-pyrrhotite mineralizations, various epigenetic veins and shear zones.

The placer gold deposits are situated within the southern part of the granulitic bedrock terrain, where rocks of igneous and sedimentary origin alternate. According to the terminology of Meriläinen (1976), the bedrock of the Ivalojoki study area can be divided into two units: the Granulite Complex and the West Inari Schist Zone (Fig. 6.). The Lemmenjoki area is situated in a similar position close to the margin of the Granulite Complex.

The Granulite Complex consists mainly of garnet-quartz-feldspar gneisses with variants, and quartz-diorite gneisses are also common. Two narrow zones composed of hypersthene amphibolites, hornblende gneisses and quartz feldspar gneisses run northwest to southeast across the main gold panning area. The southern marginal zone of the Granulite Complex consists of banded hornblende gneisses. The metamorphic grade in the Granulite Complex proper is that of granulite facies; in the marginal zone it is of amphibolite facies.

The main rock types in the West Inari Schist Zone are granite gneisses, amphibolites and chlorite-amphibole rocks metamorphosed under amphibolite facies conditions.

All the above-mentioned rocks strike to north-west and dip gently to north-east. These rocks are cut by younger, usually N-S oriented veins composed of quartz-feldspar porphyres, quartz-carbonates and quartz-hematite. They may be broadly correlative in age with the post-orogenic Nattanen granites (1.8 Ga), which occur as small, isolated batholiths south of the study area (Fig. 1).

GOLD IN BEDROCK

Altogether 315 rock samples were analysed for gold and other trace metals. The gold content of the main rock types in the area was normally very low and generally below the detection limit of 2—5 ppb. Graphite- and pyrrhotite-bearing garnet gneisses, which are quite common rocks in the area, did not show elevated gold levels either, although sulphides are known as the main carriers of gold in rocks (e.g. Boyle 1979). The only auriferous rock types were epigenetic quartz-carbonate veins and an arsenopyrite-bearing shear zone found at Harrioja.

The average gold content of the quartz-carbonate veins is 0.2 ppm (19 analyses), the maximum being 3 ppm. The highest concentrations were generally encountered in the parts of the veins with the highest pyrite. The Harrioja arsenopyrite mineralization lies in a quartz-rich shear zone within the granulite complex and also contains large amounts of pyrrhotite and loellingite. The maximum gold content was 0.4 ppm. Gold seem to be bound in sulphides in this area, since no placer gold has been panned there, and it seems to be correlative with arsenic both in the Harrioja mineralization and in the quartz-carbonate veins. Arsenic also shows a good correlation with gold in till samples from the whole study area.

A boulder of vein quartz with pyrite and hematite, which are typical minerals in veins, was found to contain several small gold grains when crushed, milled and panned. This also seems to point to the veins as a source of the placer gold although gold has not been seen in the veins in the Ivalojoki area since the early, somewhat doubtful, observations mentioned in the Introduction. Local quartz-hematite veins were also considered a likely source of gold by Stigzelius (1978).

In the Mäkärärova area, some 30 km south of the present study area, microscopic native gold was found in quartz-hematite veins which yielded 2 to 6 g/t gold (Ollila 1976). Placer gold is not present in the Mäkärärova area to any considerable extent.

WEATHERED BEDROCK

In most of the test pits, which extended throughout the surficial deposits, weathered bedrock was encountered. The weathering had been sufficiently restricted, however, for the original rock type to be easy to identify. This is also shown by silicate analyses, which indicate only slight changes in the major element composition.

On the other hand, the average gold content of the weathered bedrock, 11 ppb (54 analyses), is several times higher than in unweathered bedrock. The gold content of the different rock types varies, and seems to be clearly dependent on the occurrence of graphite, samples high in graphite generally showing an elevated gold content, the maximum being 116 ppb. Thus garnet gneisses, which are often rich in graphite, had a particularly high gold content, although the unweathered graphite-rich rocks from the same localities were devoid of gold, as mentioned above. Graphite seems to form an effective gold trap during the enrichment of gold due to weathering processes, but gold was not found in the weathered bedrock by panning,

Fig. 7. A rare gold nugget composed of seven crystals found by Pekka Salonen in the Miessijoki area. SEM.

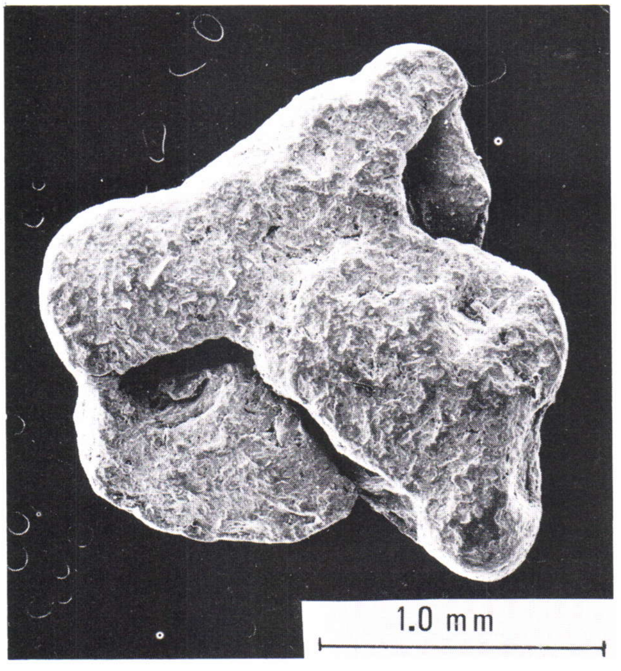

Fig. 8. An angular gold grain from Moberg. SEM.

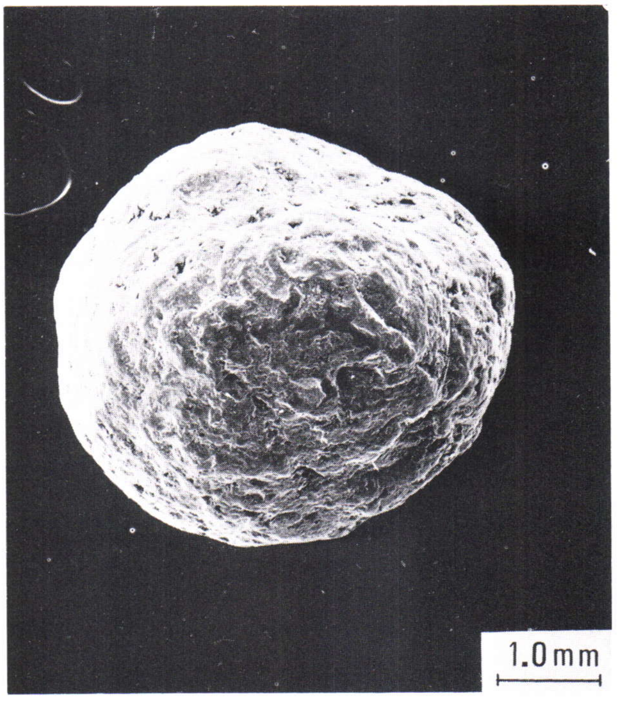

Fig. 9. A well-rounded gold grain from Moberg. SEM.

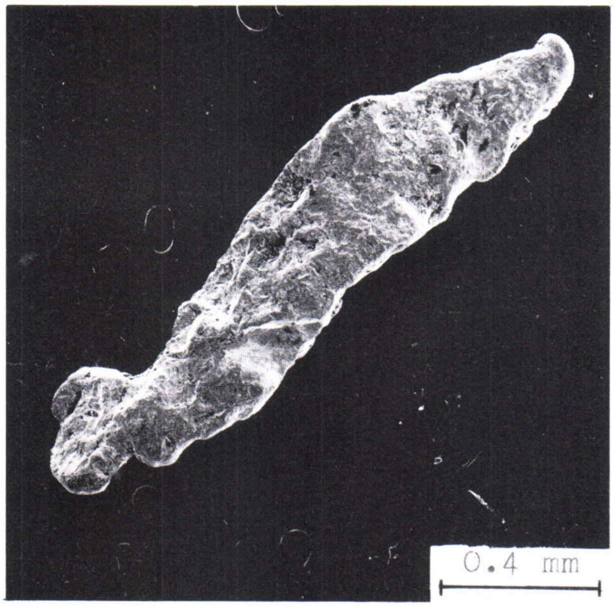

Fig. 10. A typical, longish and flat gold grain from Härkäselkä. SEM.

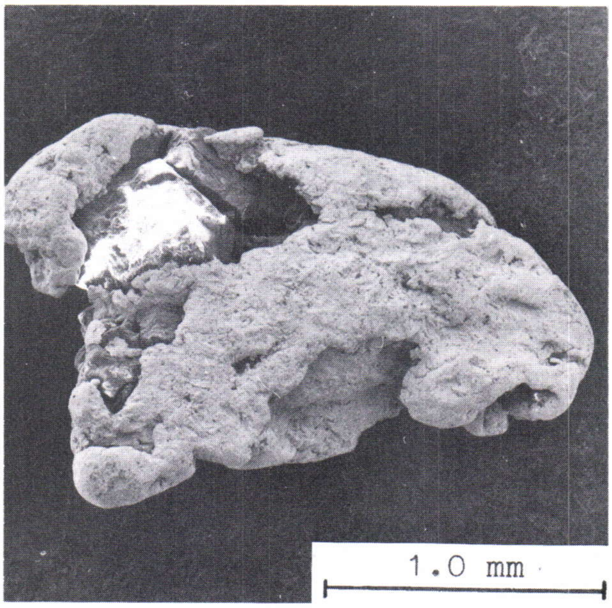

Fig. 12. A quartz-gold grain from Moberg. SEM.

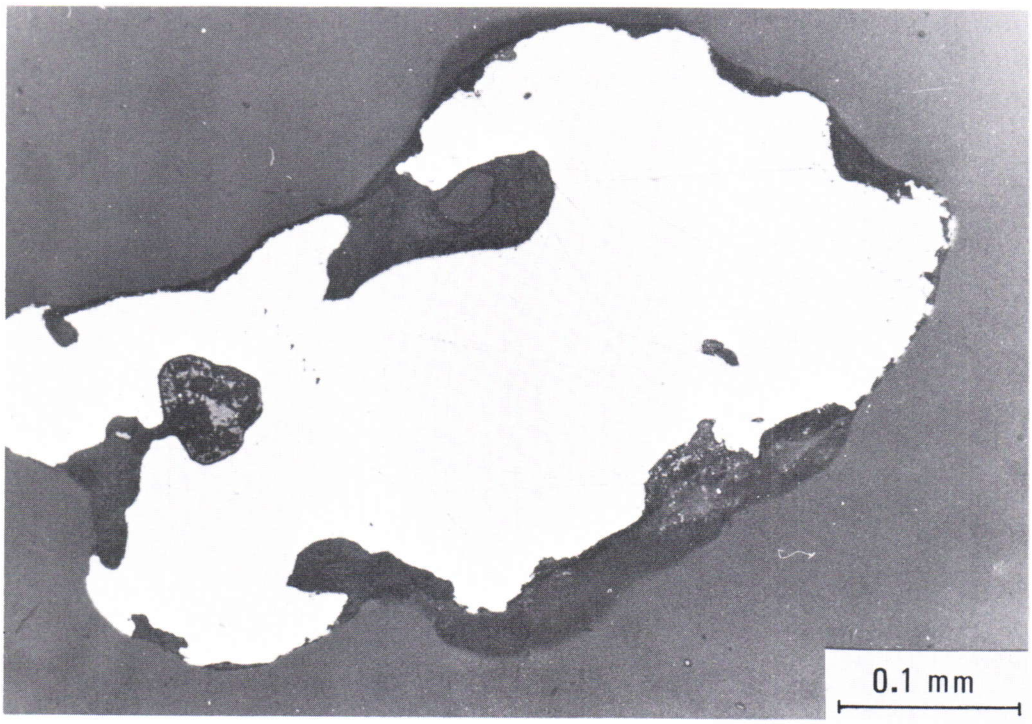

Fig. 11. A gold grain from Moberg with a lateritic matrix. Optical micrograph.

which would seem to indicate that the enrichment has taken place in a very fine-grained form from supergene solutions. This is also reflected in the even distribution of the analytical results.

COMPOSITION OF THE PLACER GOLD

The grain size of the panned gold varies from less than 0.5 mm to a few millimetres, and some large nuggets have been discovered, too. The largest of all, weighing 393 g, was found in 1935, evidently in the headwaters of the Lutto, and another, weighing 385 g, is from the nearby

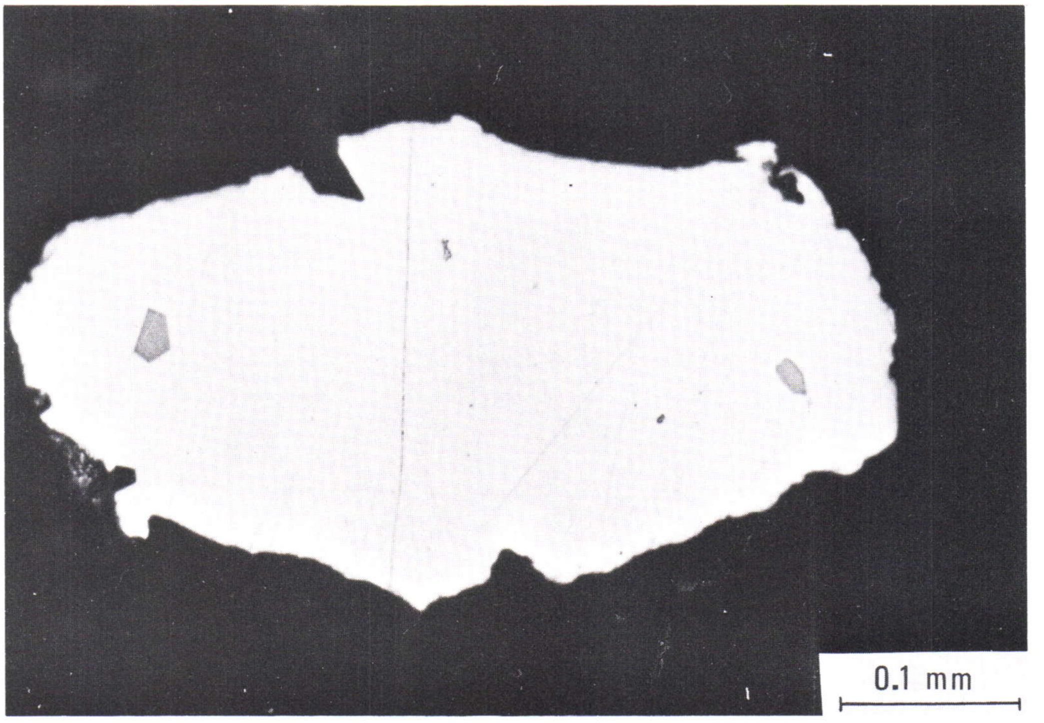

Fig. 13. A gold grain from Hangasoja with arsenopyrite inclusions. Optical micrograph.

Hangasoja area. The largest from the Lemmenjoki area, weighing 160 g, originates from the Morgamoja valley. Many of the larger specimens contain quartz, which has the appearance of being primary, as in a 183 g nugget from Tankavaara. The Geological Survey of Finland has a collection of some of the larger pieces of gold found in Finland.

The morphology of the gold grains varies a great deal. Angular, octahedral crystals are sometimes found (Figs. 7 and 8), whereas entirely rounded grains are rare (Fig. 9.). Longish, flat grains are common (Fig. 10). In places the native gold is stained by secondary oxides. Experienced gold miners believe that they are able to tell the place of origin of a piece of gold from its shape, colour and general appearance.

The mineralogy of 358 small gold grains (mostly 0.2—0.6 mm) was investigated from polished thin sections, and the composition of 142 grains was also studied by x-ray microanalysis at the Department of Electron Optics, University of Oulu. The minerals bound in the grains were identified with a scanning electron microscope equipped with an energy dispersive spectrometer (SEM + EDS).

Gold grains often contain considerable admixtures of other minerals, either bound outside the grains together with a thoroughly weathered mineral matrix or in inclusions within the grains, when they are in an entirely unweathered form.

The composition of the matrix bound to the gold grains on the outside (Fig. 11) resembles lateritic weathering: 43—55 % SiO_2, 34—39 % Al_2O_3, 5—20 % Fe_2O_3, 2—7 % TiO_2, and small quantities of Mn and K. The most common matrix mineral is quartz, and Fe and Ti oxides are also often detected (Figs. 7 and 12). Erosion-resistant minerals such as garnet, zircon and monazite were also identified.

The minerals found inside the grains are different and tend to be ones which weather easily in an oxidizing environment. The most common are pyrite, native bismuth and bismuth tellurides. Pyrrhotite, chalcopyrite and arsenopyrite were also found, together with various types of Fe-Ni-Co sulphoarsenides, galena and molybdenite, all typical minerals accompanying gold in mineralizations (see Boyle 1979) (Fig. 13). The minerals mentioned above were found only in the inner parts of the grains, whereas the outer gold-rich margins were invariably devoid of these minerals. Sometimes these minerals were so abundant inside the grains that they had the appearance of a dissemination. This seems to suggest that these gold grains originated within the mineralization rather than

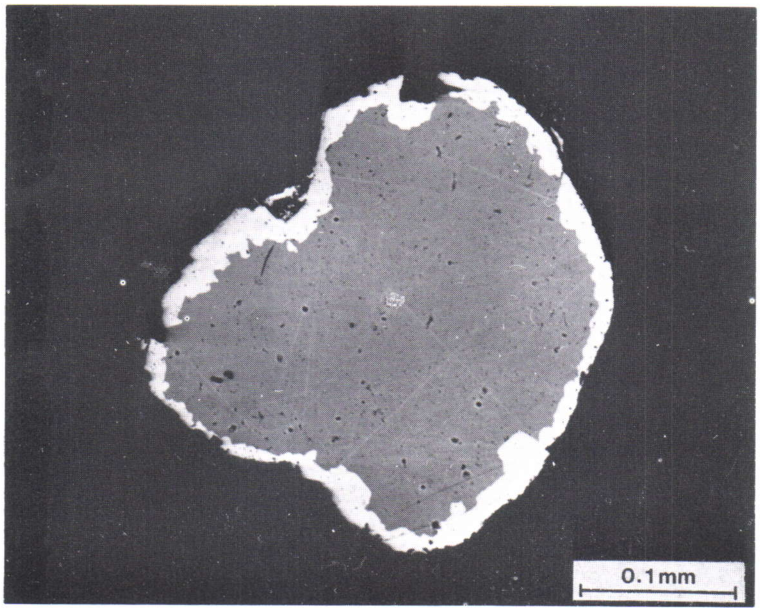

Fig. 14. A gold grain from Härkäselkä with a gold-rich rim (gold content 99.6 % as against 89 % in the core). SEM.

by precipitation from supergene solutions elsewhere in the weathering bedrock or surficial deposits.

The average silver content of the gold grains was c. 6 %, which is in accordance with earlier findings (Sundell 1936). A typical feature of the grains is a gold-rich outer margin but a poorer inner part (Figs. 14 and 15). The silver content of the outer margin is normally less than 0.5 % regardless of that of the inner part, where it varies between 0 and 47 %. The average width of the silver-poor margin is only 20 μm and at most 50 μm, and the boundary with the inner part of the grain is sharp. The sulphides are altogether lacking from the outer margin of the grains, only relics of the original crystals in the form of iron hydroxides sometimes being found. Because these relic crystals are entirely in the gold-rich margin and do not extent to the inner part of the grain, it seems that silver, too, was leached out during weathering (cf. Desborough 1970, Koshman & Yugay 1972).

Copper was also found regularly in detectable amounts inside the grains, varying between 0.01 and 1.36 % and averaging c. 0.2 %. No clear zonation was found in the copper content of the gold grains, but it was only when the copper in the inner part amounted to more than 0.2 % that it decreased regularly at the outer margin (Fig. 15).

There are areal differences in the silver and copper content of the gold grains, and in the Ag/Au and Cu/Au ratios. Gold panned from the West Inari Schist zone or from the margin of the Granulite Complex contains approximately twice as much silver as that found within the Granulite Complex proper, where it tends to be rich in copper. In the Härkäselkä area, inside the Granulite Complex, the grains are somewhat exceptional and vary greatly in composition.

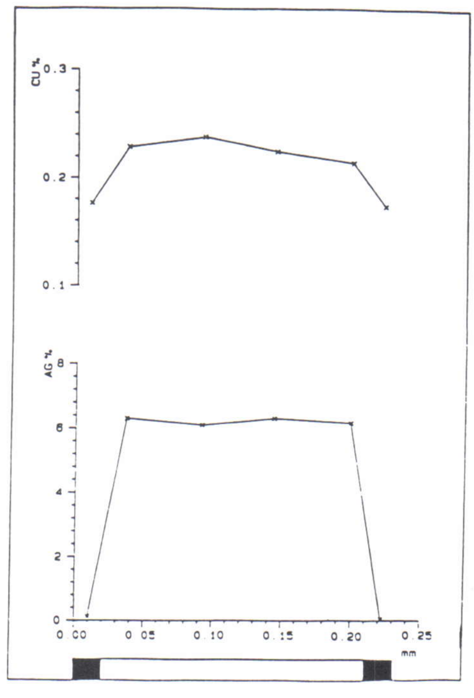

Fig. 15. Electron microprobe step-scan profile across a gold grain showing the distribution of copper and silver. Black bars indicate the gold-rich rim of the grain.

This can be attributed to the heterogeneity of the till lithology, which involves both very local and long-distance material, the latter originating from the marginal zone of the Granulite Complex and from the West Inari Schist Zone.

ORIGIN OF THE PLACER GOLD, A SUMMARY

The mineralogy of the gold nuggets, especially the presence of angular quartz, and the composition of the heavy mineral concentrate suggest that the epigenetic hydrothermic mineralized veins within the Granulite Complex proper are the obvious source of placer gold, as suggested by Fircks (1906, see also Stigzelius 1978). The gold content of the veins is normally low, 0.2 ppm, but some rich samples have also been discovered. The gold grains found in a boulder composed of vein quartz, pyrite and hematite also point to the same origin. Veins of various size are abundant in the principal panning areas, e.g. at Hangasselkä. Further evidence is provided by the good correlation between gold and arsenic in both the veins and the till. Vein quartz and panned gold are also correlative in the till.

In all likelihood the native gold originates from mineralizations in the bedrock, as shown by the presence of readily weathering sulphide minerals, such as pyrite and pyrrhotite and also various bismuth minerals in a number of the gold grains investigated. These minerals are entirely lacking from the silver-poor outer margins of the grains, suggesting leaching together with silver probably after the gold grains had been dislodged from the mineralization. The mineralogical differences within the veins, i.e. quartz-carbonate or quartz-hematite, may merely reflect differences in the country rocks. Similarly, the Ag/Au and Cu/Au ratios of the gold grains seem to depend on the bedrock composition, another factor possibly implying local provenance of the gold, since the metal ratios within the Granulite Complex differ from those in its marginal zone and the West Inari Schist Zone.

The only other source of elevated gold levels in the bedrock, apart from the quartz veins, is the arsenopyrite mineralization of the Harrioja, where no placer gold has been panned; all other types of unweathered rock were practically devoid of gold. Graphite, a significant constituent of granulite, seems to form an effective gold trap during the weathering process, and unweathered graphite-rich rocks are devoid of gold. The moderate enrichment of gold due to weathering and the presence of graphite do not, however, explain the origin of the native gold grains.

Other possible sources of placer gold besides the veins were also considered. The reasonably good correlation between panned gold and chlorite amphibole rocks and between gold and amphibolites in till would seem to indicate that the gold may originate from the marginal zone of the Granulite Complex or from the West Inari Schist Zone, where these rocks occur in abundance, i.e. 10 to 20 km from the main placer area in the direction of the glacier transport. Moreover, the Ag/Au and Cu/Au ratios in the gold grains panned there differ from those within the granulitic bedrock. The origin of the gold in the marginal zone and adjacent areas could not be confirmed from the present, rather limited bedrock data, however.

In summary, it may be stated that placer gold has been concentrated by preglacial weathering of the mineralized quartz-rich veins, where native gold was originally formed. Further enrichment has been due to fluvial and glaciofluvial processes. The role of the latter has been significant because most placers are situated in glacial meltwater channels varying markedly in size.

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