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MORPHOLOGY AND GEOCHEMISTRY OF GOLD IN A LATERITIC PROFILE, BEASLEY CREEK, LAVERTON, WESTERN AUSTRALIA

Ph. Freyssinet and C.R.M. Butt

CRC LEME OPEN FILE REPORT 6

November 1998

(CSIRO Division of Minerals and Geochemistry Report MG60R, 1988. Second impression 1998)

CRC LEME is an unincorporated joint venture between The Australian National University, University of Canberra, Australian Geological Survey Organisation and CSIRO Exploration and Mining, established and supported under the Australian Government's Cooperative Research Centres Program.

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Headquarters: CRC LEME c/o CSIRO Exploration and Mining, Private Bag, PO Wembley, Western Australia, 6014

RESEARCH ARISING FROM CSIRO/AMIRA REGOLITH GEOCHEMISTRY PROJECTS 1987-1993

In 1987, CSIRO commenced a series of multi-client research projects in regolith geology and geochemistry which were sponsored by companies in the Australian mining industry, through the Australian Mineral Industries Research Association Limited (AMIRA). The initial research program, "Exploration for concealed gold deposits, Yilgarn Block, Western Australia" (1987-1993) had the aim of developing improved geological, geochemical and geophysical methods for mineral exploration that would facilitate the location of blind, buried or deeply weathered gold deposits. The program included the following projects:

P240: Laterite geochemistry for detecting concealed mineral deposits (1987-1991). Leader: Dr R.E. Smith.
Its scope was development of methods for sampling and interpretation of multi-element laterite geochemistry data and application of multi-element techniques to gold and polymetallic mineral exploration in weathered terrain. The project emphasised viewing laterite geochemical dispersion patterns in their regolith-landform context at local and district scales. It was supported by 30 companies.

P241: Gold and associated elements in the regolith - dispersion processes and implications for exploration (1987-1991). Leader: Dr C.R.M. Butt.
The project investigated the distribution of ore and indicator elements in the regolith. It included studies of the mineralogical and geochemical characteristics of weathered ore deposits and wall rocks, and the chemical controls on element dispersion and concentration during regolith evolution. This was to increase the effectiveness of geochemical exploration in weathered terrain through improved understanding of weathering processes. It was supported by 26 companies.

These projects represented "an opportunity for the mineral industry to participate in a multi-disciplinary program of geoscience research aimed at developing new geological, geochemical and geophysical methods for exploration in deeply weathered Archaean terrains". This initiative recognised the unique opportunities, created by exploration and open-cut mining, to conduct detailed studies of the weathered zone, with particular emphasis on the near-surface expression of gold mineralisation. The skills of existing and specially recruited research staff from the Floreat Park and North Ryde laboratories (of the then Divisions of Minerals and Geochemistry, and Mineral Physics and Mineralogy, subsequently Exploration Geoscience and later Exploration and Mining) were integrated to form a task force with expertise in geology, mineralogy, geochemistry and geophysics. Several staff participated in more than one project. Following completion of the original projects, two continuation projects were developed.

P240A: Geochemical exploration in complex lateritic environments of the Yilgarn Craton, Western Australia (1991-1993). Leaders: Drs R.E. Smith and R.R. Anand.
The approach of viewing geochemical dispersion within a well-controlled and well-understood regolith-landform and bedrock framework at detailed and district scales continued. In this extension, focus was particularly on areas of transported cover and on more complex lateritic environments typified by the Kalgoorlie regional study. This was supported by 17 companies.

P241A: Gold and associated elements in the regolith - dispersion processes and implications for exploration. Leader: Dr. C.R.M. Butt.
The significance of gold mobilisation under present-day conditions, particularly the important relationship with pedogenic carbonate, was investigated further. In addition, attention was focussed on the recognition of primary lithologies from their weathered equivalents. This project was supported by 14 companies.

Although the confidentiality periods of the research reports have expired, the last in December 1994, they have not been made public until now. Publishing the reports through the CRC LEME Report Series is seen as an appropriate means of doing this. By making available the results of the research and the authors' interpretations, it is hoped that the reports will provide source data for future research and be useful for teaching. CRC LEME acknowledges the Australian Mineral Industries Research Association and CSIRO Division of Exploration and Mining for authorisation to publish these reports. It is intended that publication of the reports will be a substantial additional factor in transferring technology to aid the Australian Mineral Industry.

This report (CRC LEME Open File Report 6) is a Second impression (second printing) of CSIRO, Division of Minerals and Geochemistry Restricted Report MG60R, first issued in 1988, which formed part of the CSIRO/AMIRA Project P241.

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PREFACE

The CSIRO-AMIRA project "Exploration for Concealed Gold Deposits, Yilgarn Block, Western Australia" has as its overall aim the development of improved geological, geochemical and geophysical methods for mineral exploration that will facilitate the location of blind, concealed or deeply weathered gold deposits.

This Report presents results of research conducted as part of Module 2 of this project (AMIRA Project 241):

"Gold and Associated Elements in the Regolith - Dispersion Processes and Implications for Exploration".

The Objectives of this Module are:

I. To obtain a better understanding of the nature and genesis of lateritic and supergene gold deposits.
II. To determine characteristics useful for exploration, especially in areas of transported overburden, for:
    (a) further lateritic and supergene deposits, and
    (b) primary mineralization - including that with no expression as appreciable secondary mineralizaton.
III. To increase knowledge of the properties and genesis of the regolith.
IV. To provide data applicable for exploration for other commodities in and beneath the regolith.

The aim of the study reported herein has been to obtain information concerning the nature and origin of gold in the regolith by examining the morphological and geochemical characteristics of gold particles. The location, shape, degree of corrosion and composition of the particles may indicate the aspects of the genetic history not only of the gold itself but also of the regolith in which it occurs. The results will be compared with those of similar studies conducted in West and Central Africa, where lateritic weathering profiles have not been modified by a change to arid conditions.

C.R.M. Butt
Project Leader
November 1988

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MORPHOLOGY AND GEOCHEMISTRY OF GOLD IN A LATERITIC PROFILE, BEASLEY CREEK, LAVERTON, WESTERN AUSTRALIA

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ABSTRACT

The morphology and geochemistry of gold grains was studied in panned concentrates from several depths in the weathering profile of gold mineralization at Beasley Creek, near Laverton. At 70 - 80m depth, the mineralization is only partly weathered and both primary and secondary gold grains are present. The former are characterized by high Ag contents (maximum 48%), whereas the secondary gold is of high fineness. Above 60m, only secondary grains were found, but with several morphological types including flat polygonal forms, euhedral prismatic crystals and pseudo-hexagonal crystals. Most of the grains are etched and corroded. Above 20m, a further generation of secondary gold appears, as irregular rounded grains that are only weakly corroded. No trace elements were detected in the primary gold, but Fe and As are present sporadically in the secondary grains, probably as micro-inclusions of Fe oxides.

INTRODUCTION

The objective of this study was to examine the morphology and chemical composition of gold grains in a lateritic weathering profile as part of the broader research programme of the Weathering Processes module of the CSIRO/AMIRA Gold Project. The techniques are essentially the same as those used for similar studies in West Africa by one author (P. Freyssinet). The results from studies in Western Australia and West Africa will permit comparison of the behaviour of gold in areas which have a common history of lateritic weathering followed by different post-lateritic regimes, namely arid and humid savanna.

GEOLOGICAL SETTING AND SAMPLING

The Beasley Creek gold deposit is situated in the Mt. Margaret anticline, which has granite at the centre overlain by ultramafic rocks, komatiites and amphibolites. Some banded iron formation occurs along contacts. The mineralization seems to be confined to a mixed basaltic and komatiitic suite.

The gold deposit is located in an intensely weathered zone some 200m wide, apparently associated with a sedimentary unit. The ore zone and some of the country rocks are extensively oxidized. The mineralized zone itself is 15 to 40m wide and dips east at 45 degrees. Gold appears to be associated with quartz veins within a biotite alteration zone. The highest gold grades lie in dark, iron oxide-quartz rocks.

The deposit is on a slight rise capped by patchily developed ironstones and calcretes, with colluvial-alluvial plains to either side. The gold is dispersed in a 400m wide secondary halo of 20-40ppb in the surface.

SAMPLING, SAMPLE PREPARATION AND METHODS

Eight bulk samples, 10-15kg each, were collected; six were percussion drill samples, representing the high grade zones of the mineralization at different depths (KGL 36-40) and two samples were from the ferruginous pisolitic horizon in the surface halo (KGL 34-35). Brief sample descriptions are given in Appendix A. The samples were processed as follows:

Crushing: the total sample was jaw crushed to about 5mm, then ground in a disc mill to 1.5mm.

Panning: sample were washed to remove clays, and panned to 5-10g or less. The residue was panned further on a micropanner. It should be noted that the data discussed in this report refer only to the grains that can be recovered by this procedure. A high proportion of grains smaller than 10 μm will have been lost, with moderate losses of those between 10 and 20 μm.

Optical examination: the gold grains were removed, and examined and measured using a binocular microscope.

Scanning electron microscopy: grain morphology was examined by SEM and the Ag contents determined semi-quantitatively using an energy dispersive spectrometer.

Polished sections: selected gold grains were examined in polished section.

Cameca SX50 electron microprobe: selected grains were analysed for Au, Ag, Cu, Ni, Fe, S and As.

GRAIN SIZE DISTRIBUTION

All gold particles have been measured and, although there were insufficient grains to obtain significant statistics, the following distribution is apparent:

fresh mineralization, 72-80m, grain size 25-200 μm;
oxidized mineralization, 10-60m, grain size 50-100 μm;
surface halo, in the ferruginous horizon and calcrete concretions, grain size 30-70 μm.

MORPHOLOGY OF GOLD GRAINS

Partly weathered mineralization, 72-80m

Gold grains at this depth are of several types:

1. *Primary grains.* These are Ag-rich grains that are either xenomorphic (photo 1), with large faces derived from the impression of surrounding crystals, or euhedral (photo 2).
2. *Etched primary grains.* These are very rounded grains with surfaces covered by numerous etching pits. Such grains are Ag-rich, although some faces have a layer of gold of high fineness - possibly due to secondary precipitation (photo 3). Small (1 μm) spherules of high fineness gold can also be observed adhering to the surfaces of the corroded grains. This feature seems characteristic of early stages of secondary gold development near the primary source.

3. *Secondary gold.* These are grains 15-30 μm in size that have no detectable Ag on their surfaces. The grains are flattened with highly corroded surfaces, but appear to be euhedral, with characteristic polygonal forms (photo 4).

Oxidized mineralization, 30-60m depth

All the grains are of very high fineness and are probably secondary. No Ag-bearing, and hence probably residual, primary grains, were found. Most of the grains are xenomorphic, with large faces from the impression of the surrounding crystals (photo 5-6); however, their general polygonal form could be euhedral. This morphology is characteristic of gold precipitating among in quartz crystals. There are also some euhedral, prismatic crystals (photo 8). Most of the grains are weakly etched, but usually only particular crystal faces are attacked so that the original morphologies are still recognizable.

Oxidized mineralization, 10 - 30m depth

There are two groups of gold grains, both secondary. The first group consists of strongly etched pseudo-hexagonal (photo 9), prismatic (photo 10) or flat, polygonal crystals. The second group consists of uncorroded or only weakly etched rounded (photo 12-13) or irregular grains (photo 11).

Surface halo

The pisolitic soil, derived from underlying lateritic duricrust, has numerous indurated ferruginous fragments in a red clayey matrix. Only two grains were recovered, both being highly corroded prismatic crystals (photo 14).

The calcrete contains numerous ferruginous pisoliths. Again, only two grains were recovered. One grain is almost completely corroded and has a "spongy" form, although some crystal faces are partly preserved (photo 15). The other grain is polygonal and possibly euhedral, but has smooth uncorroded surfaces (photo 16).

The presence of two morphological types in the top 30m could indicate at least two generations of secondary gold. There is an older generation, mostly of well crystallized grains, that has been partly dissolved and a second generation that has precipitated in rounded and irregular shapes and appears to be unweathered.

CHEMICAL COMPOSITION OF GOLD PARTICLES

Analytical conditions

The chemical composition of the gold particles has been determined by electron microprobe analysis of polished sections of grain mounts. The following seven elements were determined: Au, Ag, Cu, Fe, Ni, As and S. The detection limits and counting times are shown in Table I. (NB. Only a very small number of samples was available for analysis, so that the results can only be treated qualitatively in determining compositional trends.)

	Ag	Cu	Ni	Fe	S	As
Detection limit (ppm)	720	180	160	160	200	160
Counting time (seconds)	40	40	40	40	100	140

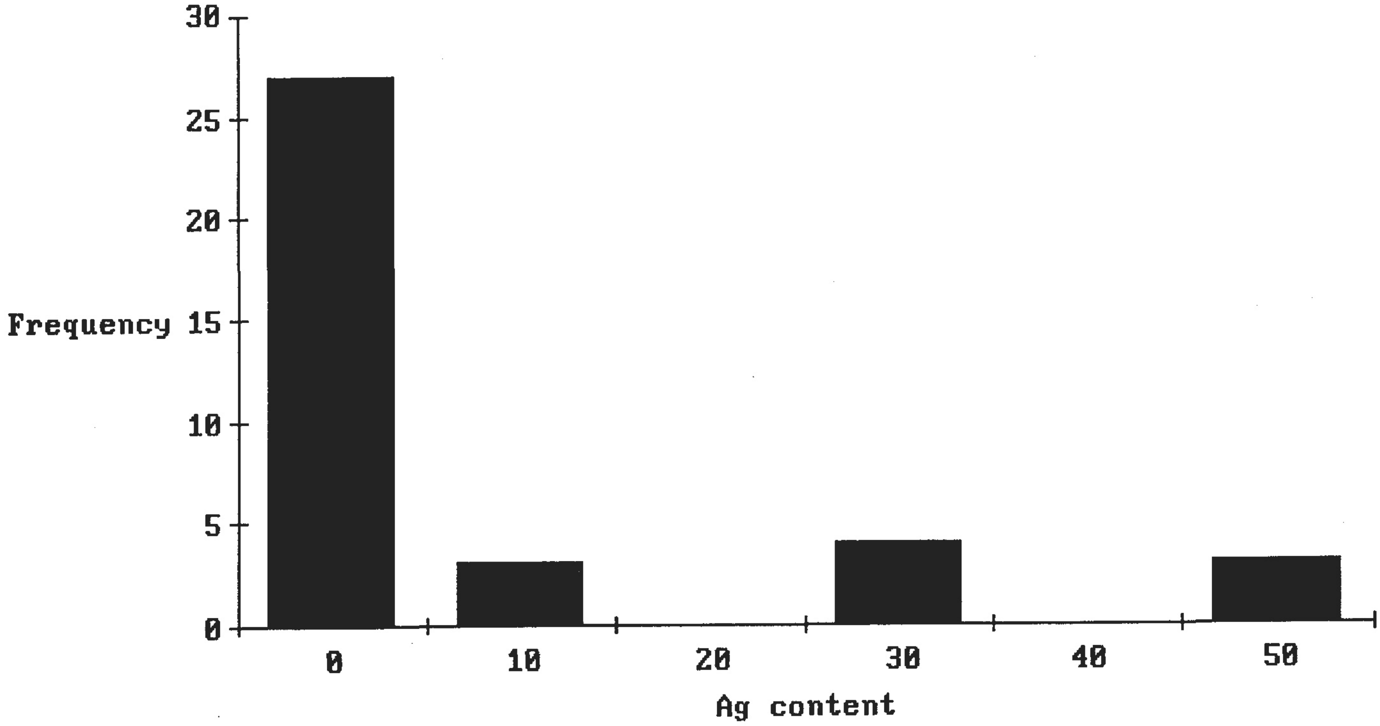
Table 1: Detection limits and counting times for electron microprobe analysis. Counting time for Au: 20 seconds. The results for S are not reliable at this level.

Gold and silver distribution

Silver is the only element, other than gold, present as a major component. There are two clearly separate populations of gold grains (Figure 1), those with 16 to 48% Ag and those containing <720ppm Ag (ie below detection limit). The few grains containing 16 to 48% Ag are from the deepest samples at 72-80m, in which the mineralization is only slightly weathered. Although there is some variation between grains, the Ag distribution within each grain is uniform, varying by less than 1% Ag. Higher in the profile, all grains are of very high fineness, containing <720ppm Ag.

Trace element distributions

The results of the trace element analyses are given in Table II, subdivided into the two classes of particles indicated by the Ag content. Whereas the distribution of Ag is generally uniform within the grains, that of trace elements such as Fe, Cu and Ni is erratic and seems to represent discrete inclusions of iron oxides or even sulphides. The Ag-rich grains are not enriched in any particular element, whereas several of the Ag-poor grains have localized high concentrations of Fe and As in



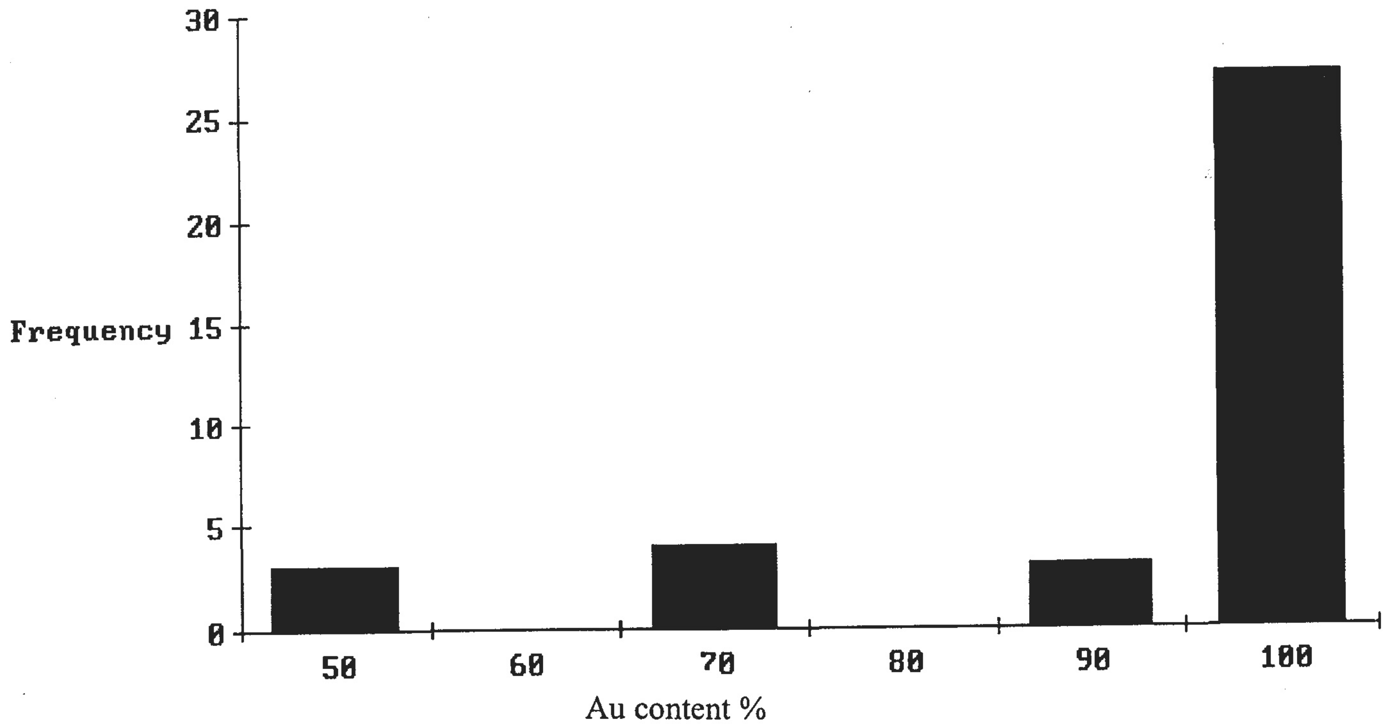


Figure 1: Frequency distribution of gold and silver in gold grains

particular. A possible interpretation is that these grains have inclusions of fine Fe oxides or even As oxides, incorporated during the precipitation of secondary gold.

Class (Ag%)	No. Samples	Au %	Ag %	Cu ppm	Fe ppm	As ppm	Ni ppm	S ppm
>0.5%	10	68	30	0	19	0	0	15
<0.5%	27	100	0	17	195	9	47	77

Table 2: Average chemical composition of gold particles classified according to silver content.

CONCLUSION

Study of the morphology and geochemistry of gold particles from several depths in the weathering profile leads to the following conclusions:

1. At 72-80m depth, mineralization is only partly weathered and both primary and secondary gold particles are present. The former are characterized by high Ag contents (maximum 48% Ag), whereas the secondary gold is of high fineness.
2. Between a depth of 60m and the surface, all grains seem to be secondary but there are several morphological types present, including flat polygonal forms, euhedral prismatic crystals and pseudo-hexagonal crystals. Most of the grains are etched and corroded. The corrosion is particularly evident at 20-10m depth; however, at that depth, weakly corroded rounded and irregular grains appear. The presence of these two different grain types suggests that there are at least two generations of secondary gold, the first comprising well crystallized particles that have subsequently been partly dissolved, and the second of only slightly corroded rounded and irregularly shaped grains.

The chemical analysis of secondary gold particles shows that trace elements, mainly Fe and As, are present only sporadically, probably as small inclusions of Fe or As oxides within the gold matrix. The trace elements were all below detection limit in primary gold.

PLATE 1

GOLD GRAINS IN PARTLY WEATHERED MINERALIZATION AT 72-80m

Photo 1: KGL 48. Xenomorphic primary grain characterized by large square and smooth faces representing the impression of surrounding crystals. The striations on one face suggest these crystals were probably pyrite. No corrosion. High silver content.

Photo 2: KGL 48. Euhedral prismatic primary grain. Some rounding, weakly etched on the edges but with mostly smooth crystal faces. One face has a large etching pit. High silver content.

Photo 3: KGL 48. Compact xenomorphic primary grain. Strongly corroded on one side (right) so that the primary features have disappeared, but primary faces are observable though rounded on the left. A patchy surface coating of secondary gold (light grey) is present overlying the primary gold (dark grey). Small spherules of secondary gold are adhering to the surface.

Photo 4: KGL 48. Flat polygonal crystal of secondary gold with the large face showing the impression of the adjacent crystal. No detectable silver.

GOLD GRAINS FROM OXIDIZED MINERALIZATION AT 30-60m

Photo 5: KGL 38. Secondary gold similar to photo 4. Flat polygonal crystal with the large face showing the impression of the adjacent crystal. No corrosion. No detectable silver.

Photo 6: KGL 37. Secondary gold similar to photo 5, but corroded. The surface is covered by numerous etching pits. No detectable silver.

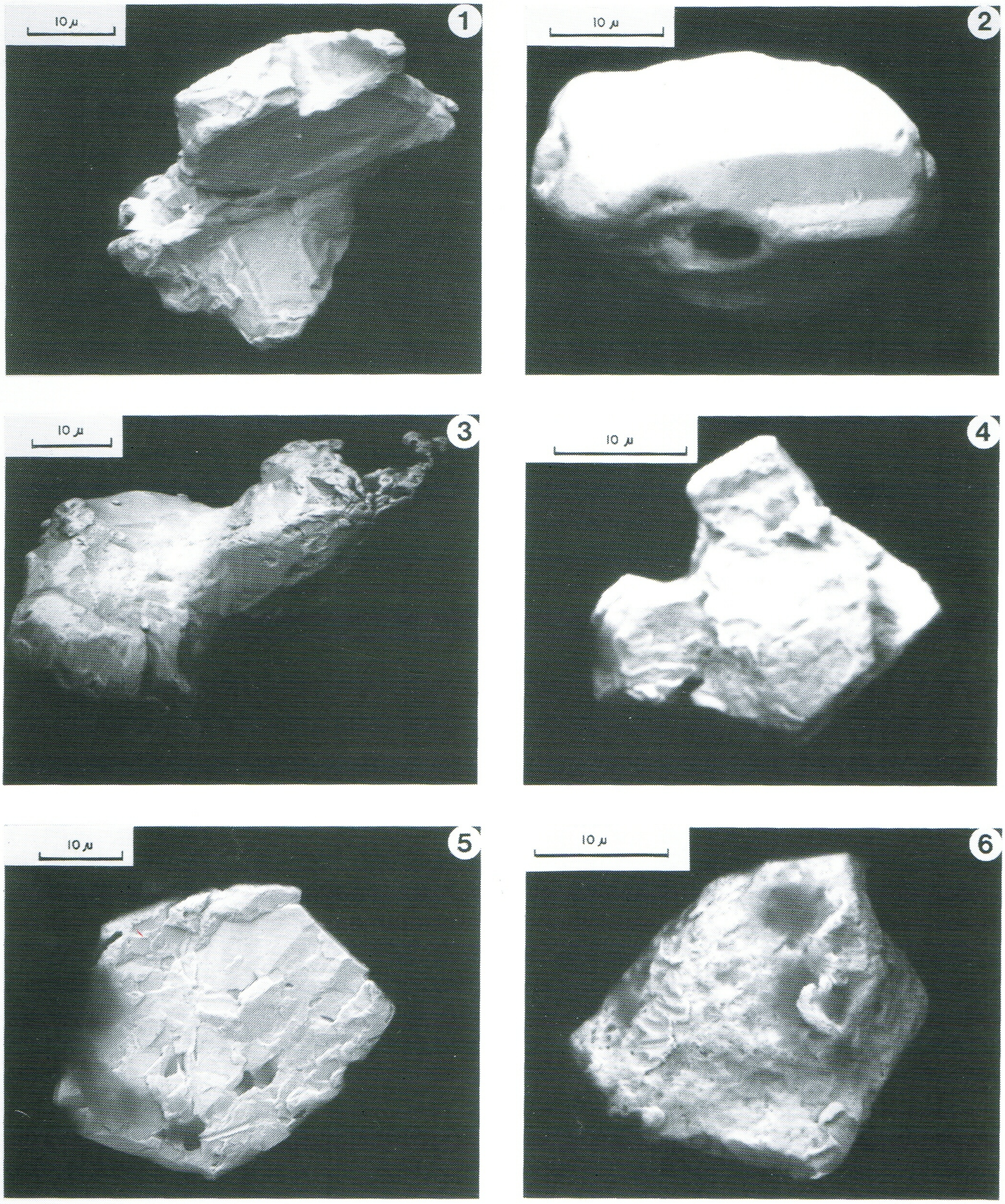

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PLATE 2

GOLD GRAINS FROM OXIDIZED MINERALIZATION AT 30-60m

Photo 7: KGL 37. Xenomorphic secondary gold, rounded and with large etching pits. An ilmenite crystal is adhering to the gold grain. No detectable silver.

Photo 8: KGL 37. Euhedral prismatic crystal of secondary gold with only one corroded face. No detectable silver.

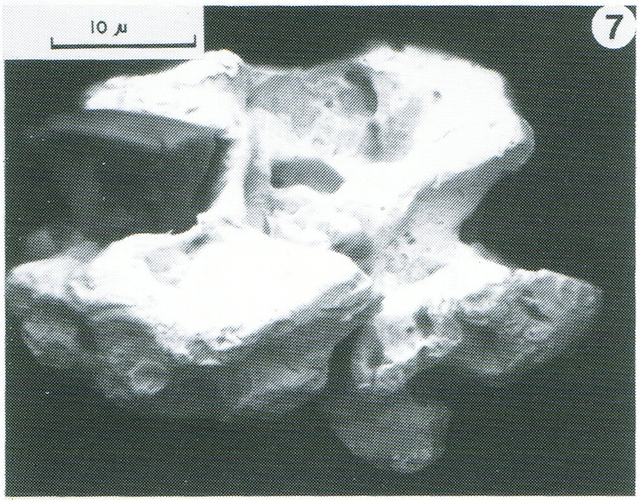
GOLD GRAINS FROM OXIDIZED MINERALIZATION AT 10-30m

Photo 9: KGL 36. Flat pseudohexagonal crystal of secondary gold. Strongly corroded. Cavities are filled with iron oxides. No detectable silver.

Photo 10: KGL 36. Euhedral prismatic crystal of secondary gold. Strongly corroded and rounded. No detectable silver.

Photo 11: KGL 36. Aggregate of several crystals of secondary gold, including a pseudohexagonal crystal towards the bottom. The grain has a gold coating which seems to post-date the euhedral crystals. No detectable silver.

Photo 12: KGL 36. Partly corroded globular grain of secondary gold. Some small spherules of secondary gold are present in the large depression at the centre. High fineness gold.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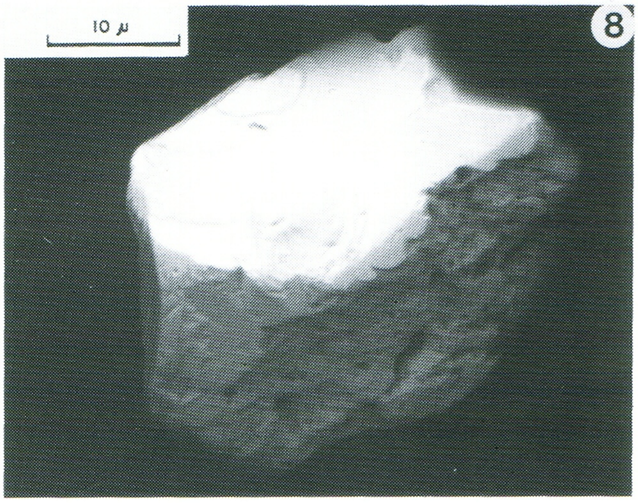
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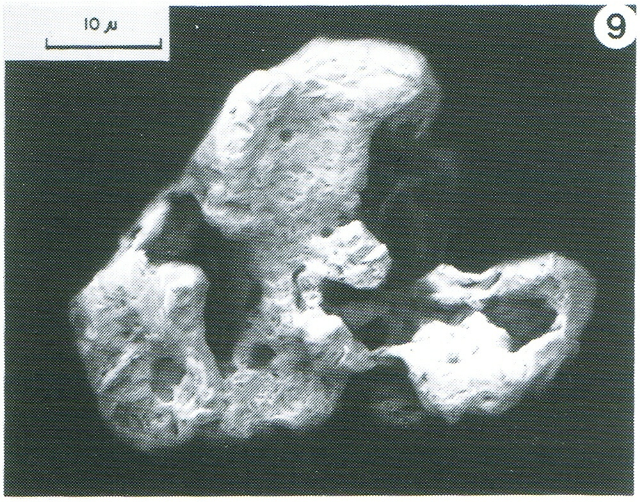
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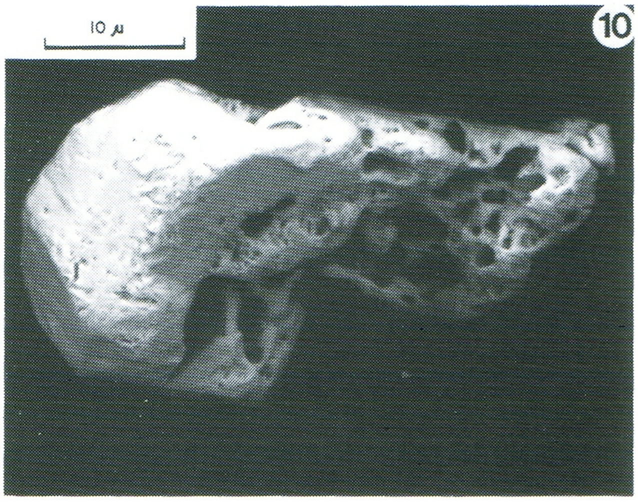
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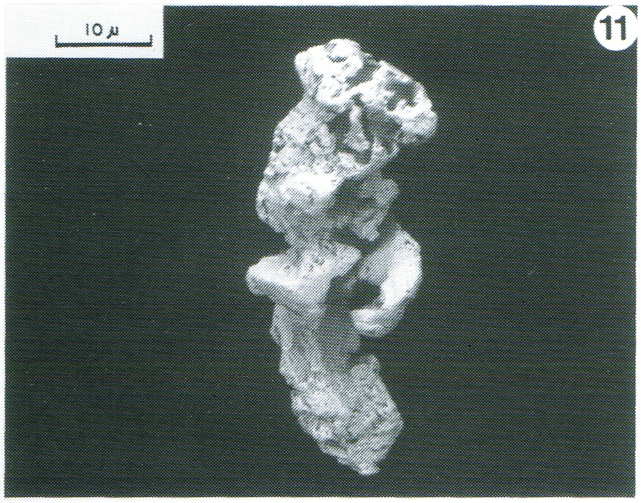
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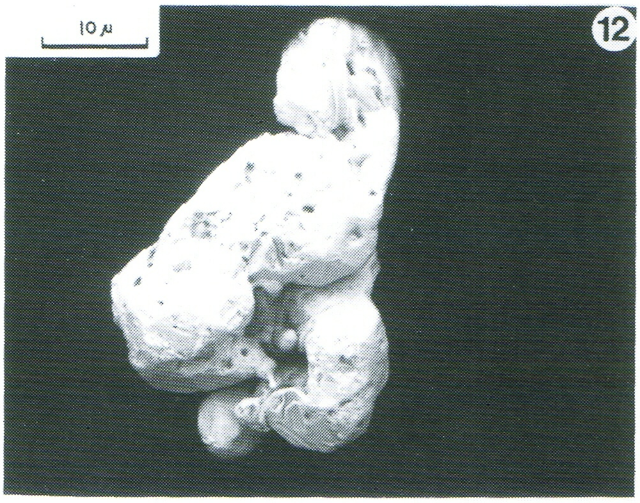
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PLATE 3

GOLD GRAINS FROM OXIDIZED MINERALIZATION AT 10-30m

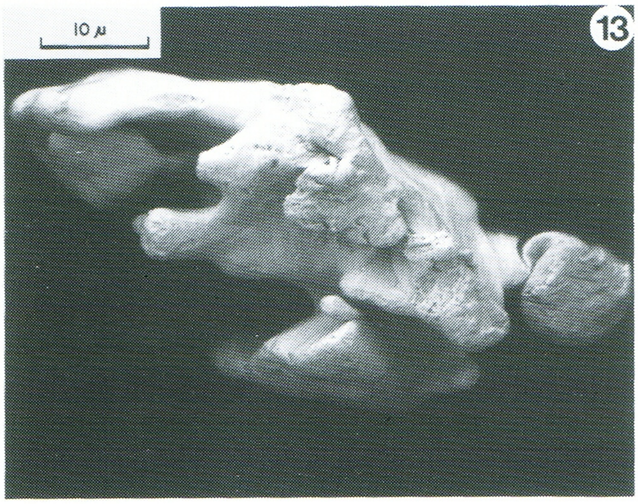
Photo 13: KGL 36. Secondary gold. Similar to photo 12 but less corroded.

GOLD GRAINS IN THE SURFACE HALO

Photo 14: KGL 34. Secondary gold from the ferruginous horizon. Euhedral prismatic crystal strongly corroded and rounded. No detectable silver.

Photo 15: KGL 35. Secondary gold from the calcrete. The grain is more or less euhedral, but has a "spongy" appearance due to extreme corrosion and the development of numerous etching pits. However, some crystal faces are partly preserved. No detectable silver.

Photo 16: KGL 35. Polygonal grain of secondary gold from calcrete. Probably euhedral, with smooth, uncorroded surfaces. No detectable silver.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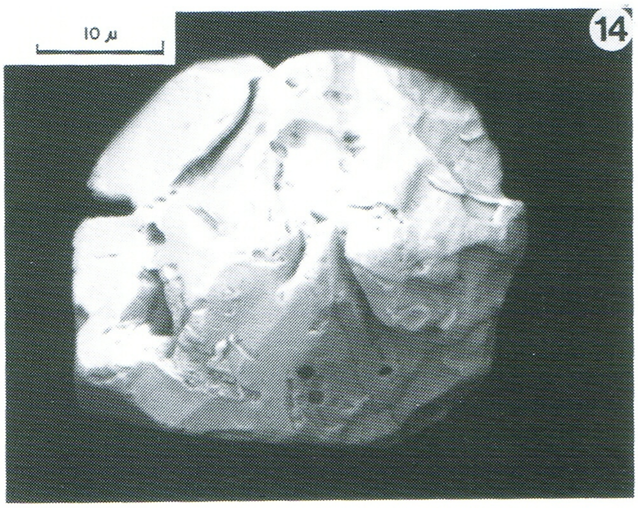
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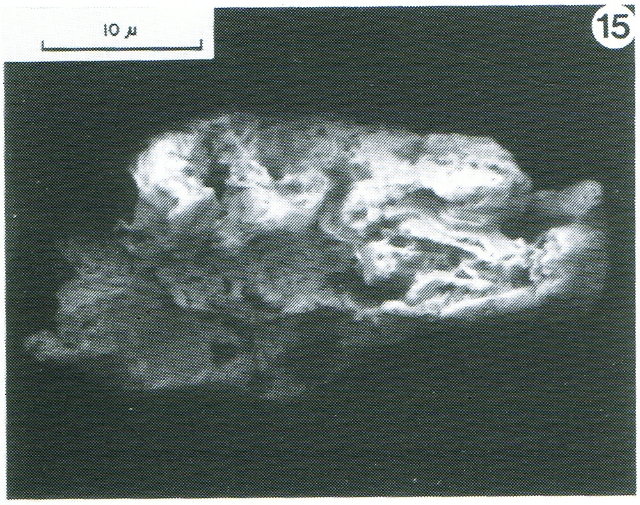
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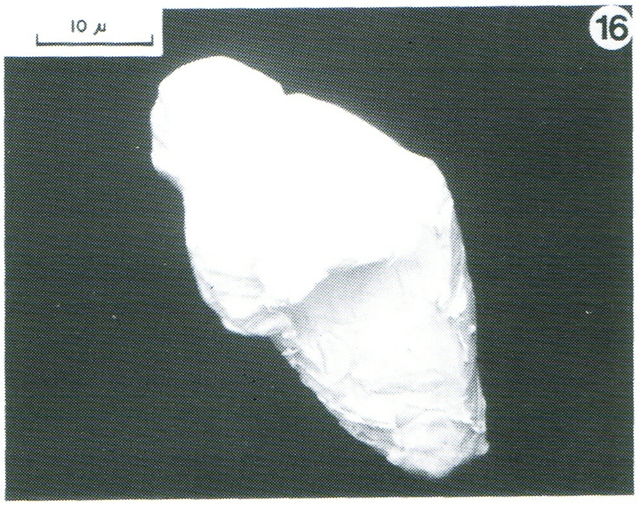
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APPENDIX A

SAMPLE DESCRIPTIONS

KGL 34: BCP 40 0-3m. Ferruginous horizon. Pisolitic layer with a red clayey matrix. Anomalous surface halo. Gold grade about 40ppb.

KGL 35: Calcrete nodules on the surface, enclosing ferruginous pisoliths. The calcrete matrix is partly silicified.

KGL 36: BCP 40. Mineralization at 17-21m.

KGL 37: BCP 40. Mineralization at 29-48m.

KGL 38: BCP 41. Mineralization at 43-52m.

KGl 39: BCP 42. Mineralization at 66-74m.

KGL 40: BCP 43. Mineralization at 66-74m.

KGL 48: Similar to KGL 40. Mineralization at 72-80m.