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MINERALOGY AND GEOCHEMISTRY OF SOME WEATHERED ROCKS FROM CALLION GOLD DEPOSIT, YILGARN BLOCK, WESTERN AUSTRALIA

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CRC LEME OPEN FILE REPORT 15

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(CSIRO Division of Exploration Geoscience Report 43R, 1989. Second impression 1998)

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CRC LEME is an unincorporated joint venture between The Australian National University, University of Canberra, Australian Geological Survey Organisation and CSIRO Exploration and Mining
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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 15) is a Second impression (second printing) of CSIRO, Division of Exploration Geoscience Restricted Report 043R, first issued in 1989, 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 mineralization.

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.

In particular, this report details the mineralogy and geochemistry of weathered mineralized basalts and of an allochthonous formation exposed in the BC pit, in relation to an understanding of regolith formation and exploration techniques.

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SUMMARY

Weathered profiles at Callion are the host of economic gold mineralization. This report starts the documentation of these profiles, which ultimately will enable us to understand the weathering processes and the distribution of gold and associated elements in the weathered profile. Data reported here concern the mineralogy and geochemistry of the upper weathered wall-rocks from the BC Pit at the northern end of the Callion mineralization.

Two geological formations were characterised, showing slightly different compositions.

The in-situ weathered rock is essentially composed of kaolinite and quartz gradually replaced by goethite. With the progressive decrease of Al and Si and the concentration of Fe, we observed a progressive dispersion of Ti, Mg, K, Na, Cl, Sr and Y and concentration of S and Cu.

An allochthonous formation at the northern end of the BC pit is composed mainly of hematite, goethite and alunite. In this formation, Si, Ba, Cu and Zn show a depletion whereas Ti, S, CO_2, As, Cr and Zr are concentrated. The presence of alunite indicates the presence at some stage of sulfate-rich groundwaters.

1. INTRODUCTION

This study is part of the AMIRA Project 241, the aim of which is to help exploration for supergene or primary concealed gold deposits, through a better understanding of the formation of the weathered profile and behaviour of gold and other elements during weathering processes. For this purpose, deposits and prospects presenting a variety of rock-types, primary ore types, geomorphology and climate have been selected, the Callion area being one of them. The objectives of the work at Callion are specifically to study:

- The distribution of gold in the weathered profile
- The nature and characteristics of host rocks in the weathered profile
- The dispersion of pathfinder elements

This report gives preliminary results of a mineralogical and geochemical study of the initial 30 samples from the BC pit collected in June 1987.

2. BACKGROUND

The Callion area, situated 100 km NW of Kalgoorlie, is almost flat, showing only very low hills with slopes below 5° and covered with schlerophyll bush. The climate is presently semi-arid with a winter rainfall of ~200 mm. Evaporation far exceeds precipitation. A drainage channel occurs over the old underground workings, but the BC pit is elevated and occurs near the crest of a laterite-capped ridge.

The major rocks in the Callion area are metabasalts of the Archaean Norseman-Wiluna greenstone belt (Fig. 1). The metabasalts have been deeply weathered and now outcrop only occasionally through the thick lateritic cover. Within the metabasalts are a number of quartz-filled shear zones, some of which contain economic gold mineralization (Glasson et al., 1988). The Callion quartz vein system is several metres wide and hundreds of metres long. It is N-S steeply dipping to the east, subparallel to the stratigraphic units (Glasson et al., 1988).

Gold was first discovered at Callion in 1895. From 1899 until 1956, several companies mined the Callion deposit, and recovered a total of 2302 kg of gold from 146 tonnes of ore (Glasson et al., 1988) from underground workings.

BC pit is located at the northern end of the Callion mineralization. There within the upper weathered zone, gold occurs both in quartz veins and in lateritic "cover".

3. SAMPLING

The initial 30 samples were collected from the base of the 5 m deep BC open pit which exposes the upper part of the weathered zone (Fig. 2).

In this part of the pit, from south to north, there is a nodular grey weathered rock gradually passing to soft yellow-brown-reddish material which splits into polyhedra of about 10 mm diameter.

Towards the northern end there is a zone of soft darker red material which is clearly transported for it contains numerous fragments, mainly hard ferruginous gravels and pebbles. It also includes soft white balls, a few centimeters in diameter, which become more numerous towards the centre of the formation. This formation occupies all the 20 m wide N wall of the pit. On top of this formation and a few metres away from the edge of the pit is a dislocating ferricrete several tens of centimetres thick.

Samples, reflecting variations of appearance, were collected within both autochtonoüs and allochthonous formations.

4. ANALYTICAL TECHNIQUES

A small representative part of each sample was kept as reference and for polished sections. The remaining sample of about 1 kg was then crushed and 50 g ground, using a Mn-steel jaw-crusher and ring mill. This powder was used for both X-ray diffraction (XRD) and chemical analysis.

X-ray powder diffraction patterns were obtained using a Philips PW1130 diffractometer, with CuKα radiation and graphite crystal monochromator using a scanning speed of 1° 2Θ/min from 4° to 68° 2Θ.

Mg, Al, Si, S, P, K, Ca, Ti, Mn, Fe, Zn were analysed by X-ray fluorescence spectrometry (XRF); Na, Cr, Co, Ni, Cu, Zn, Ag, Cd, Ba, Pb, Be, La, Mo, Sr, Y, Yb, by Inductively coupled plasma emission spectrometry (ICP); C by a Carbon-Leco CR-12 analyser.

Gold will be analysed by graphite furnace Atomic Absorption Spectrometry after HBr dissolution and MIBK extraction once testing has established the best technique of subsampling for gold analysis.

5. RESULTS

5.1 Mineralogical composition

X-ray powder diffractometry showed the autochtonous weathered rock in the upper part of the weathered zone consists of kaolinite, goethite, quartz and halite, in varying proportions. From S to N, kaolinite, quartz and halite progressively decrease, being replaced by goethite (Fig. 3, patterns 1 to 4). The allochthonous formation is mainly composed of hematite, goethite and alunite, the alunite constituting the white balls; kaolinite and quartz are present in small quantities (Fig. 3, patterns 5 and 6). The ferricrete is composed of hematite, gibbsite, quartz and goethite (Fig. 3, pattern 7).

5.2 Chemical composition

Both formations are composed mainly of Fe, Si and Al; Ti, Mg, K, Na, S, CO_2, Cl are present in small quantities; the main trace-elements are Ba, Cr, Cu and Zr (Table 1). Gold has not yet been determined.

In the autochtonous weathered rock, most elements show a progressive evolution from S to N, Si, Al, Ti, Mg, K, Na, Cl, Sr and Y progressively decrease, while Fe, S and Cu increase (Table 1, columns I to IV).

The allochthonous formation is poorer in Si, Ba, Cu and Zn than the underlying weathered rock, and richer in Ti, S, CO_2, As, Cr and Zr (Table 1, columns V and VI). Where the alunite is abundant S, K and Sr can be particularly high. (The presence of alunite in such a formation above S-poor weathered rocks is unusual, and indicates sulfate-rich groundwaters). The ferricrete showed complete depletion of Mg, K, Na, S, Cl, Ba and Cu, and high contents of Ti, CO_2, Cr and Zr. Al, which decreases with ferruginization of the weathered rock, may be concentrated in the allochthonous formation as alunite and gibbsite.

6. CONCLUSIONS

The host rocks in the upper part of the weathered profile in the BC pit gradually evolve from grey weathered ?basalt to soft brownish material as kaolinite and quartz are progressively replaced by goethite. As this occurs various elements, not only the majors entering the composition of these minerals, but also minors and traces, show a very gradual evolution, whether concentrating or depleting.

Some thick cemented transported materials are locally present in the BC area, as part of a palaeolake or channel. The mineralogical and chemical composition of this formation differs from that of the underlying weathered rocks. Some alunite occurs in this formation, indicating sulfate-rich palaeowaters.

7. FUTURE WORK

7.1 Microscopic and microprobe studies

These preliminary results from XRD and chemical analysis must now be completed by more detailed studies of selected samples from both autochtonous and allochthonous formations so that documentation can be completed and mechanisms understood. This will, in particular, establish whether the progressive evolution of the elements observed in the weathered rock is the result of weathering or contamination from the allochthonous materials.

7.2 Additional sampling

This initial study is of 30 samples from the upper weathered host rock in BC area. A second more substantial sampling occurred in late October-early November 1987. Then both the Callion deposit and Glasson deposit (located about 5 km south) were sampled. Samples were collected from the quartz-vein systems, the surrounding rock(s) and the more remote rock, and at various depths from the fresh rock and ore up to the surface.

The samples, about 300, were taken horizontally or vertically, using the two small existing open pits ("BC" and "Glasson"), the costeans, the drill cores or powders and the natural surface outcrops.

7.3 Proposed analytical techniques

The proposed analytical techniques are the same as those detailed above. A selection of 150 samples are being analysed by X-ray diffraction and chemical analysis (gold included). A few samples will then be selected for microscopic and microprobe studies, and possibly electron scan microscopy.

8. ACKNOWLEDGEMENTS

The Callion Joint Venture and, in particular, Mike Glasson (geologist) are greatly thanked for providing plans, logs and report, and guiding us on the site.

Samples were crushed by J.J. Davis. X-ray diffractograms were run by A.R. Horne. Chemical analyses were performed by L.E. Dotter, H.R. Han and A. Martinez all of the North Ryde laboratories of the CSIRO Institute of Minerals, Energy and Construction.

9. REFERENCES

Glasson, M.J., Lehne, R.W., Wellmer, F.W. (1988) - Exploration in the Callion area (Eastern Goldfields, Western Australia) and the discovery of the Glasson Vein. Journal of Geochemical Exploration (in press).

Table 1 Average chemical compositions from the NW part of the BC Pit. I, II, III, IV: autochtonous weathered rock. V, VI: allochthonous formation. VII ferricrete. (X) number of samples. Major components, wt%; minors, ppm.

	I (9)	II (7)	III (2)	IV (2)	V (3)	VI (2)	VII (1)
SiO_2	46.41	39.27	28.27	18.43	13.87	12.40	3.67
Fe_2O_3	14.63	23.22	40.31	50.83	56.53	45.00	59.15
Al_2O_3	24.72	22.62	16.02	15.38	10.79	18.52	22.33
TiO_2	1.22	1.16	0.84	0.64	4.80	2.36	3.14
MgO	0.26	0.25	0.12	0.13	0.20	0.15	(<0.1)
K_2O	0.34	0.13	0.08	0.09	<0.04	0.97	(<0.04)
Na	0.48	0.42	0.35	0.24	0.37	0.53	(<0.01)
CaO	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.04
MnO_2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
SO_3	0.39	0.45	0.70	0.74	1.22	7.40	(0.15)
CO_2	0.36	0.48	0.49	0.47	1.00	0.84	0.92
Cl	0.64	0.60	0.55	0.35	0.57	0.38	(0.02)
P_2O_5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.12
Loss	11.93	12.46	12.87	13.74	12.51	13.46	11.40
Total	101.4	101.0	100.6	101.0	101.8	102.0	100.9
Ag	<5	<5	<5	<5	<5	<5	<5
As	6	<5	<5	<5	12	21	<5
Ba	163	127	254	131	13	42	(<10)
Be	3	3	<2	2	5	4	5
Cd	<5	<5	<5	<5	<5	<5	<5
Co	13	16	8	14	8	5	14
Cr	126	178	160	175	303	385	450
Cu	218	392	500	540	119	104	(16)
La	<20	<20	<20	<20	<20	<20	<20
Mo	<10	<10	<10	<10	<10	<10	<10
Ni	31	52	44	53	<20	<20	45
Pb	<50	<50	<50	<50	<50	<50	<50
Sr	9	8	6	<5	7	172	5
Y	11	7	3	1	2	<1	3
Yb	<1	<1	<1	<1	<1	<1	<1
Zn	49	58	29	17	18	10	14
Zr	160	129	143	122	391	214	269

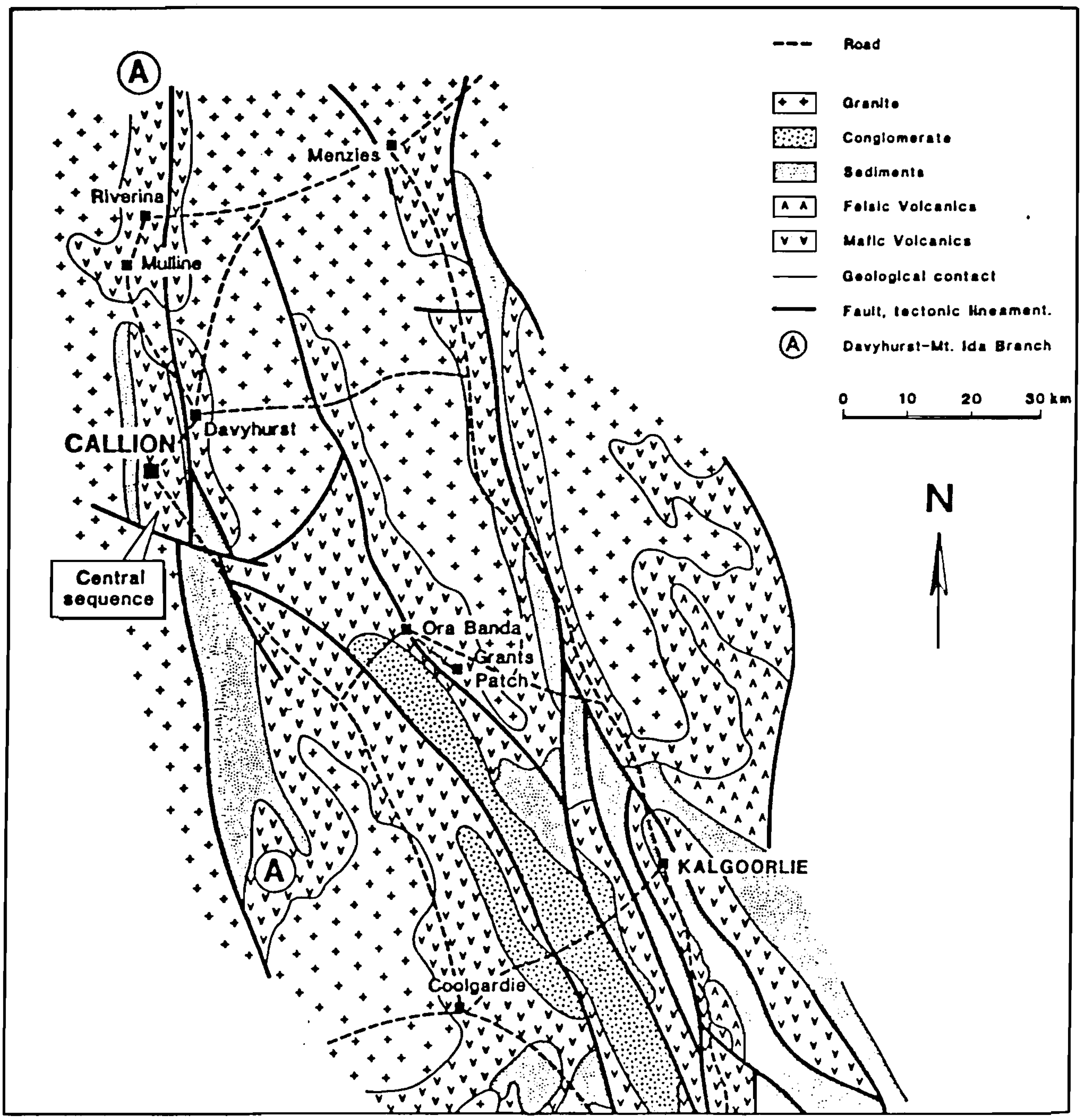
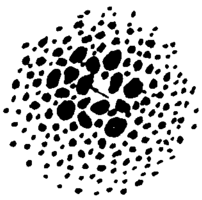


Fig. 1 - Generalized geologic map of the Callion Area, after Glasson et al., 1988



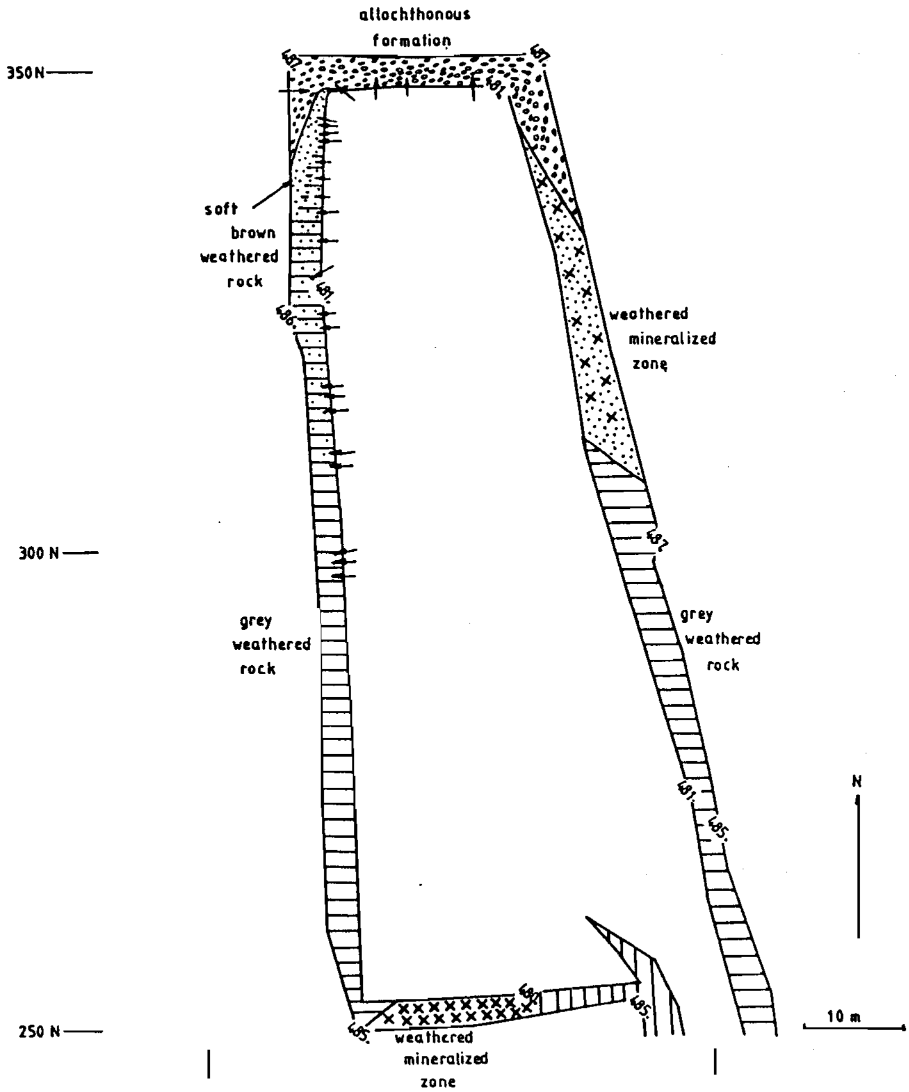


Fig. 2 - **BC Pit showing sample locations (→)**

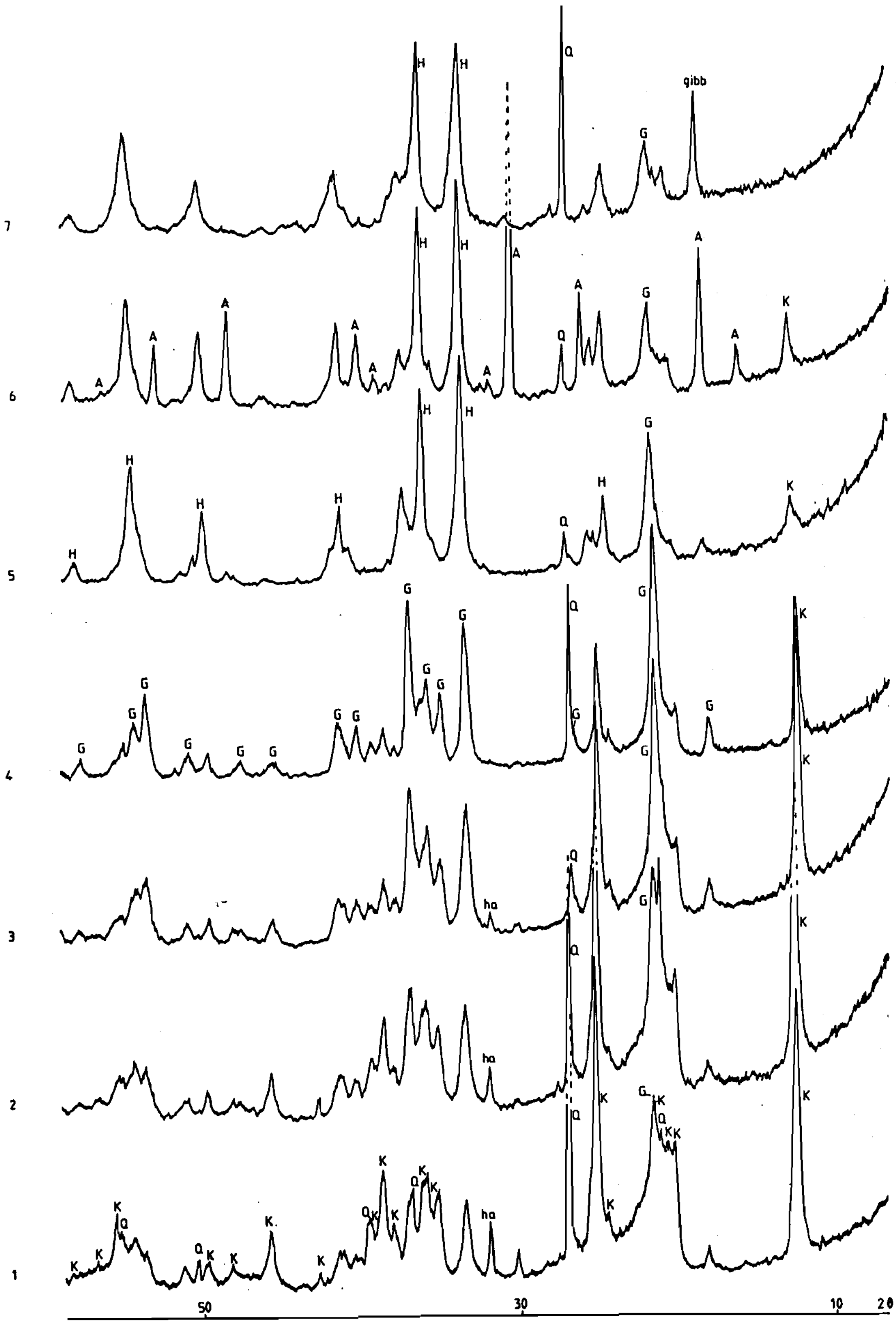


Fig. 3 - Representative X-ray diffraction patterns from the NW part of the BC Pit
1,2,3,4: autochtonous weathered rock. 5,6: allochtonous formation.
7: ferricrete
K kaolinte, Q quartz, G goethite, H hematite, A alunite, gibb gibbsite
ha halite