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MINERALOGICAL INVESTIGATION OF BACTERIAL LEACH RESIDUES OF ORE FROM DENISON MINES LTD. ELLIOT LAKE, ONTARIO

by

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EXTRACTION METALLURGY DIVISION

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M. R. Hughson* and S. Kaiman**

SUMMARY

Mineralogical investigation of test residues from bacterial leaching, one test of minus 4 plus 8 mesh material after 19 weeks of leaching and the other of minus 8 plus 14 mesh material after 33 weeks of leaching, showed that the leach solutions had completely pervaded the ore grains of both samples. The extraction of uranium is in part due to dissolution of uraninite which appears to be complete after 19 weeks. Brannerite too appears to have been completely altered after 19 weeks leaving only uranium-bearing particles of anatase or anatase and rutile from which uranium continues to be extracted. Monazite and coffinite are not affected by the leach solutions. Iron is being removed by a slow surface reaction on particles of pyrite leaving an amorphous residue of unknown composition.

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INTRODUCTION

Residue samples from two bacterial leaching tests (Nos. 6 and 10) and the corresponding feed samples were submitted to the Mineralogy Section by Mr. V.F. Harrison on May 18, 1965. The test samples were from Lot 2 of ore from Denison Mines Ltd., Reference No. 3/65-5. Reported sample data for the two leach tests are given in Table 1. It was requested that the effect of bacterial leaching action on the uranium and sulphide minerals be determined.

TABLE 1

Bacterial Leaching Test Data

		Test No. 6	Test No. 10	
Mesh Size		- 4 + 8	- 8 + 14	
Feed	U_3O_8 %	0.14	0.14	
	Fe %	4.49	3.85	
	Ti %	0.20	0.19	
Duration of Leaching		19 weeks	19 weeks	33 weeks
Residue	U_3O_8 %	0.05	-	0.02
	Fe %	4.02	-	2.26
	Ti %	0.196	-	0.17
Extraction	U_3O_8 %	64.4	* 86.5	85.8
	Fe %	10.5	* 25.7	41.3
	Ti %	2.00	* 6.58	10.5

* Calculations based on solution and leach feed analyses.

MINERALOGY

Bacterial Leach Feed

A preliminary microscopic examination of the sized samples of feed used for the bacterial leaching tests showed that they are similar to one another and to the quartz pebble conglomerates of Blind River ores. Since these ores have been previously described in detail[1] only a brief description of the present samples will be given here. They consist of olive green grains of fine-grained quartz and sericite from the matrix of the conglomerate, and smoky grey grains of quartz from the pebbles. The most abundant metallic mineral observed in polished sections of the feed samples is pyrite which is erratically disseminated throughout grains of the quartz-sericite matrix. Also present in minor proportions in the matrix are small amounts of pyrrhotite, chalcopyrite, and galena.

Four radioactive minerals were found in the present samples. They are brannerite (Figure 1), uraninite (Figure 2), monazite (Figure 3), and coffinite (Figure 4) and they occur in the quartz-sericite matrix usually in association with pyrite. All except coffinite are fairly common. Some of the brannerite is intergrown with rutile and some with anatase which often occurs at the edges of the brannerite particle. Galena occurs in fractures in uraninite (Figure 2) and minute particles of pyrite are present in most grains of monazite and coffinite (Figures 3 and 4). Forty-eight of the fifty-three radioactive particles observed in polished sections of the feed samples measured between 200 and 100 microns in their minimum dimension indicating the usual particle size is between 65 and 150 mesh. Of these, 12 were brannerite, 34 uraninite, 5 monazite, and 2 coffinite.

A few vitreous, black nodules of the uranium-bearing hydrocarbon thucholite occur in the quartz-sericite matrix of the conglomerate (Figure 5).

Bacterial Leach Residues

Test No. 6, 19 weeks (-4+8 mesh)

The bacterial leach residue after 19 weeks has a weathered appearance: the quartz-sericite matrix grains are partly covered with an earthy yellow material. The quartz pebble grains are unaffected. Fresh pyrite surfaces exposed on the surfaces of the matrix grains are scarce in contrast to what was observed in the original feed material.

Autoradiographs were prepared by contacting polished surfaces of the 19-week residue to alpha sensitive plates for 172 to 285 hours. The autoradiographs showed that a considerable number of radioactive particles are still present in the sample. Examination of the radioactive particles with an ore microscope showed that they consist of (a) grey gangue-like particles of anatase which exhibit a strong straw-yellow internal reflection under crossed nicols (Figure 6), (b) intergrowths of anatase and bluish-grey particles of rutile (Figure 7), and (c) grey gangue-like particles of monazite. X-ray diffraction patterns of radioactive grains of type (a) and (b) above which had first been ignited at red heat, confirmed that only anatase is present or anatase and rutile and did not indicate the presence of any brannerite. Particles of uraninite are also absent from the 19-week leach residue. Coffinite is very scarce in the original feed and may also be present in this residue but its identity was not confirmed by X-ray methods. Particles of what appears to be thucholite are present but they are not radioactive.

As seen in polished section, particles of pyrite have serrated edges and are surrounded by a thin grey layer (Figure 8). This grey material also appears to have penetrated fractures and cavities in the pyrite, particularly where pyrite is exposed at the edge of the quartz-sericite grain (Figure 9). The grey layer is of fairly uniform thickness, usually between one and two microns. In some places there appear to be two grey layers rather than one. The material forming the grey layer is quite soft and in many places has been pitted during the polishing process. The narrow width of the layer made it difficult to obtain an uncontaminated specimen, however, X-ray diffraction patterns indicate it is amorphous.

Pyrrhotite is very scarce and the few particles observed are surrounded by a pitted zone. Chalcopyrite and galena particles show no evidence of leaching action.

Test No. 10, 33 weeks (-8+14 mesh)

After 33 weeks the bacterial leach residue has a cream-coloured, powdery coating on some of the quartz-sericite matrix grains. No particles of pyrite were observed on the surface of the matrix grains.

Alpha track autoradiographs of polished sections (exposed 172 to 285 hours) indicate that radioactive particles are less abundant than in the 19-week leach residue and that they are only weakly radioactive in most cases. Many of these radioactive particles are similar to the radioactive particles of anatase found in the 19-week leach residue (Figure 6). Radioactive intergrowths of rutile and anatase are rather scarce and usually only very weakly radioactive. Monazite is fairly common but uraninite and coffinite were not observed. A few particles of what appears to be nodular thucholite contain no radioactivity.

Many particles of pyrite in the 33-week residue are surrounded by a grey layer several times as thick (commonly between 5 and 7 microns) as that observed in the 19-week residue (Figure 10). Serrations in pyrite grain boundaries are usually much deeper.

Little change was observed in the pyrrhotite which is very scarce and chalcopyrite and galena are unaffected.

PHOTOMICROGRAPHS

Figure 1. A dense aggregate of lath-like crystals of brannerite (bnr) in a grain of quartz-sericite (qtz-ser). Bacterial leach feed.

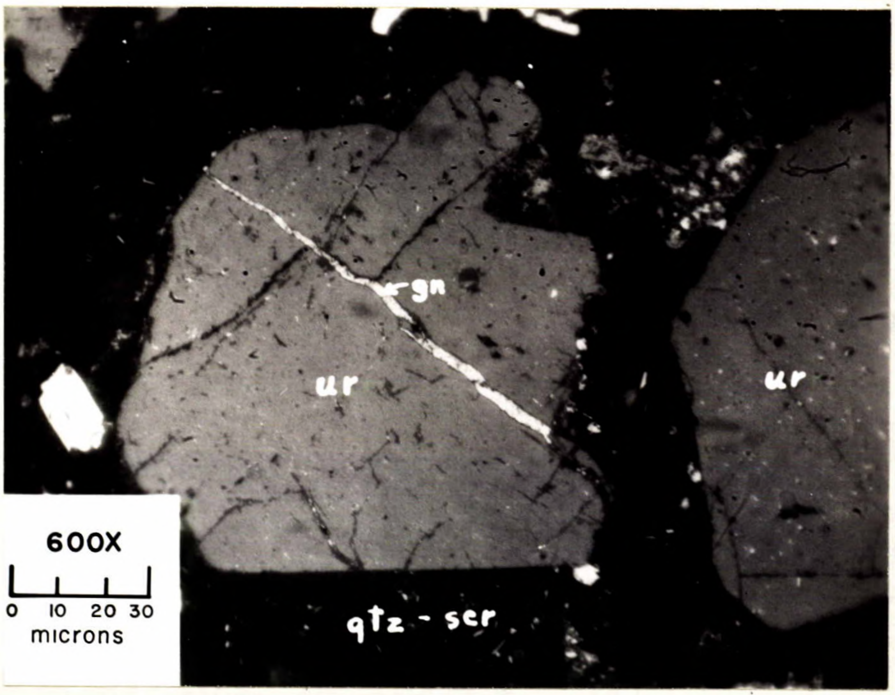

Figure 2. Crystals of uraninite (ur) in a grain of quartz-sericite(qtz-ser). Galena (gn) fills a fracture in one of the uraninite crystals. Bacterial leach feed.

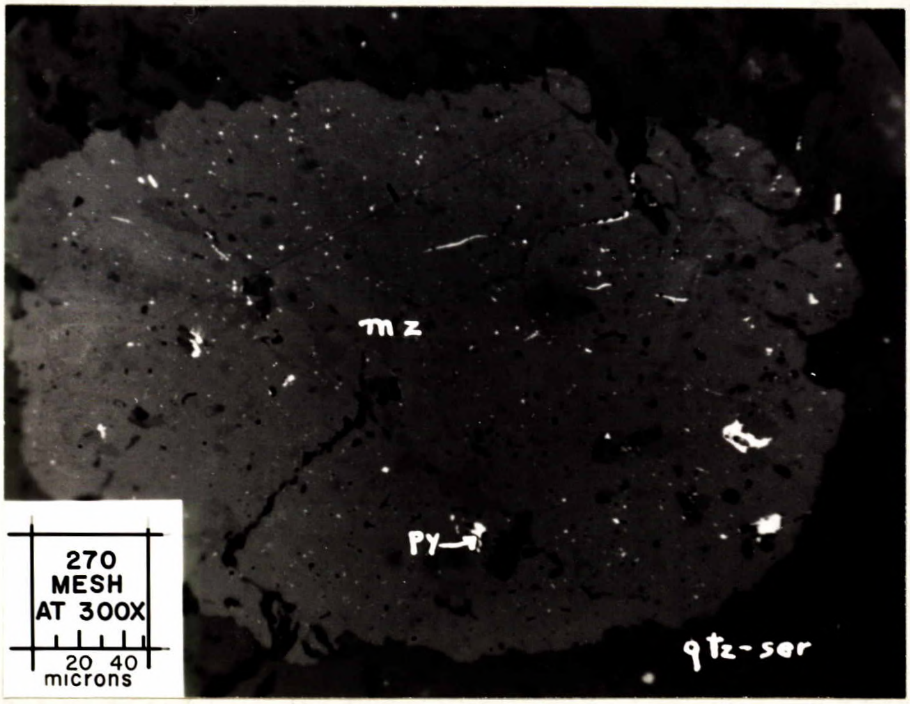

Figure 3. A rounded particle of monazite (mz) in a quartz-sericite grain (qtz-ser) contains minute particles of pyrite (py). Bacterial leach feed.

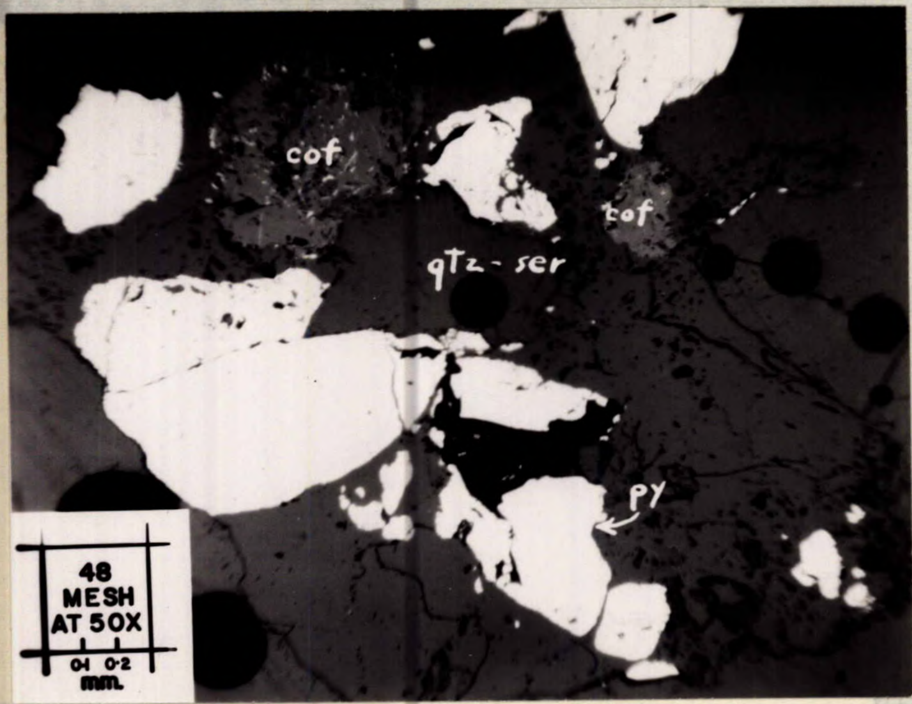

Figure 4. Irregular particles of coffinite (cof) in a grain of quartz-sericite (qtz-ser) contain minute white specks of pyrite. Coarse particles of pyrite (py) also occur in the quartz-sericite. Bacterial leach feed.

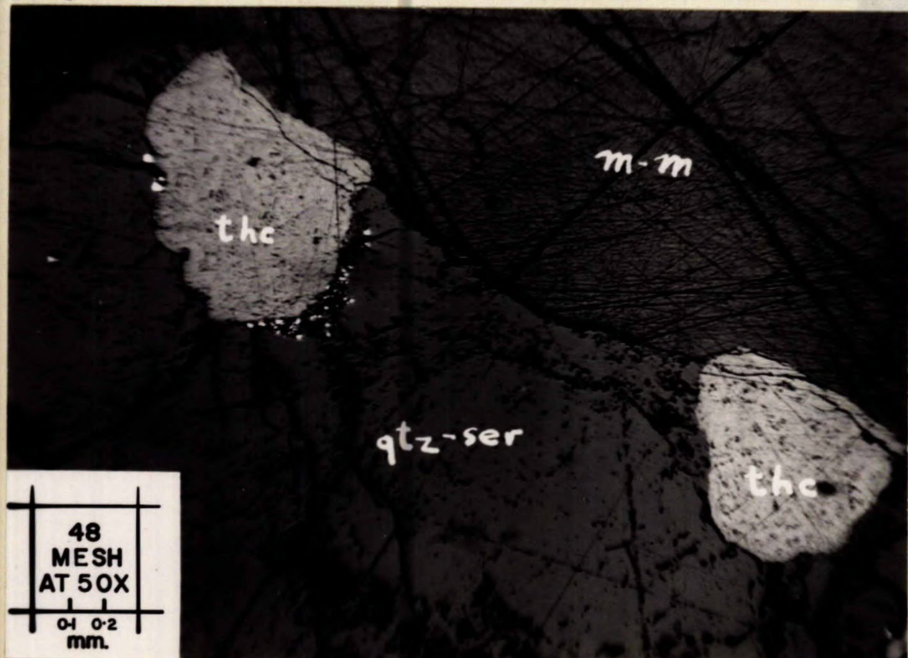

Figure 5. Nodular particles of thucholite (thc) occur at the edge of a quartz-sericite grain (qtz-ser). m-m is the mounting medium. Bacterial leach feed.

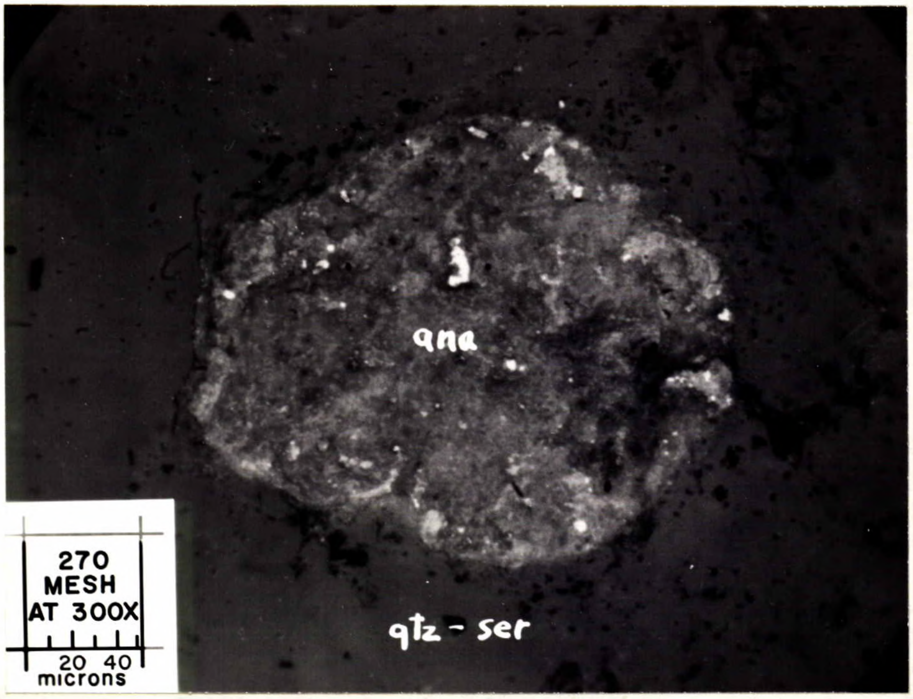

Figure 6. A radioactive particle of anatase (ana) in a quartz-sericite grain (qtz-ser). 19-week residue.

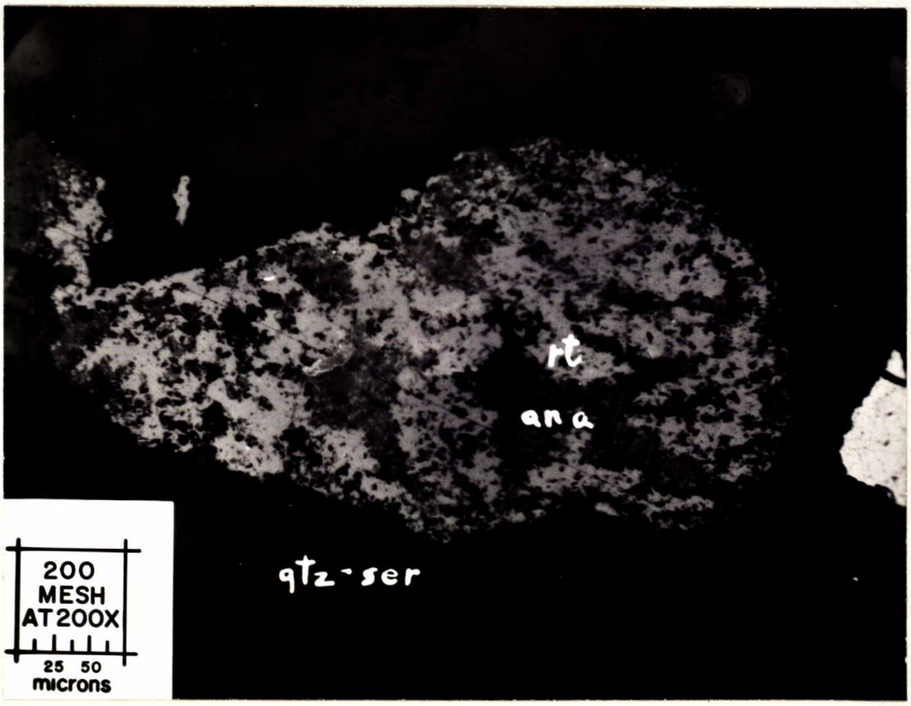

Figure 7. A radioactive particle of rutile (rt) and anatase (ana) in a grain of quartz-sericite (qtz-ser). 19-week residue.

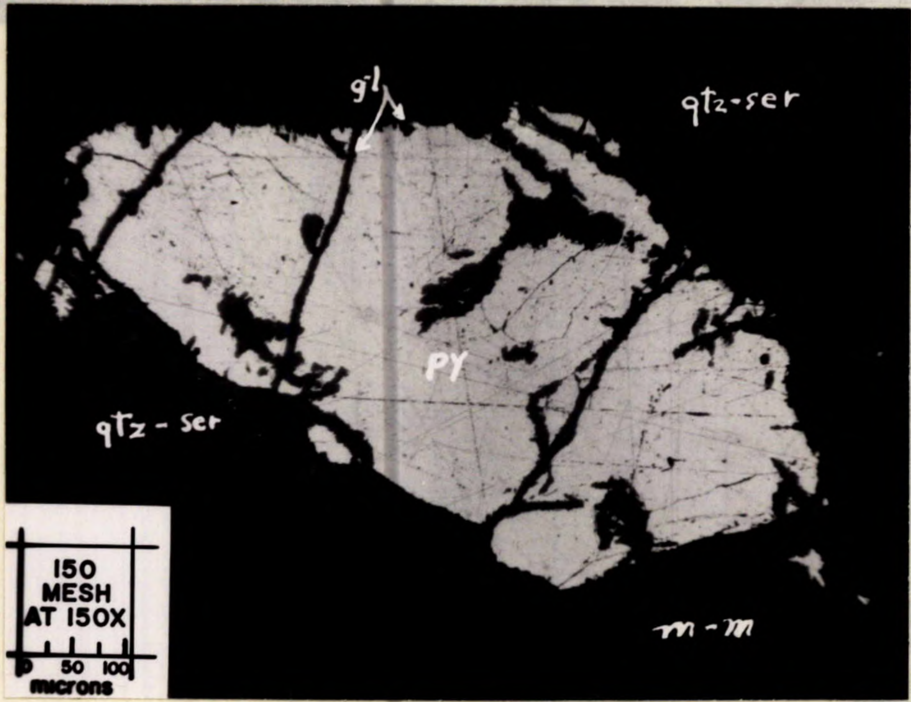

Figure 8. A particle of pyrite (py) surrounded and penetrated by a grey layer (g-l) in a grain of quartz-sericite (qtz-ser). 19-week residue.

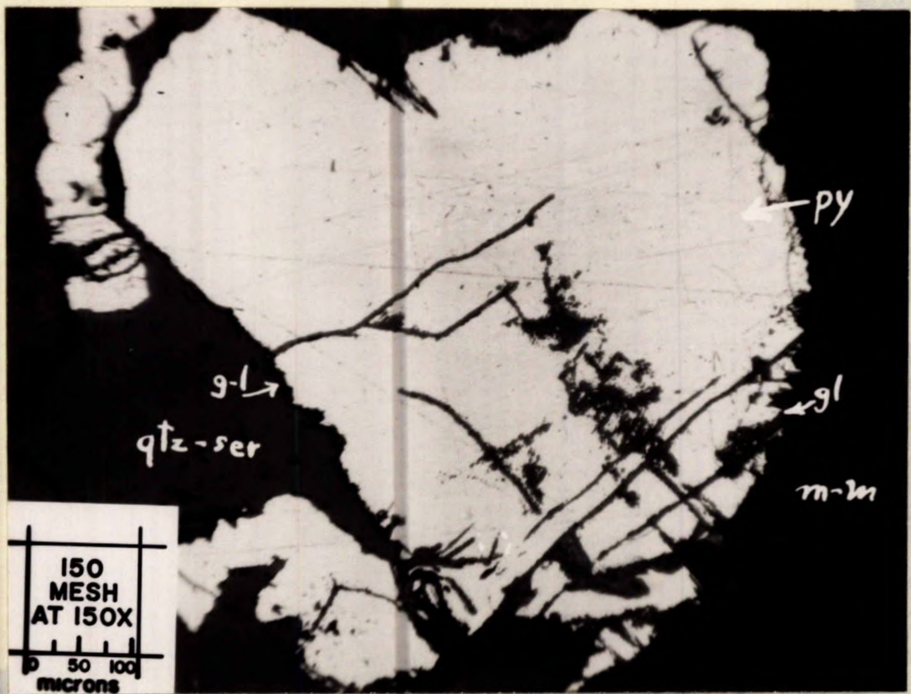

Figure 9. A particle of pyrite (py) occurring at the edge of a grain of quartz-sericite (qtz-ser) and showing more intensive alteration on exposed side of grain. Mounting medium m-m on right. 19-week residue.

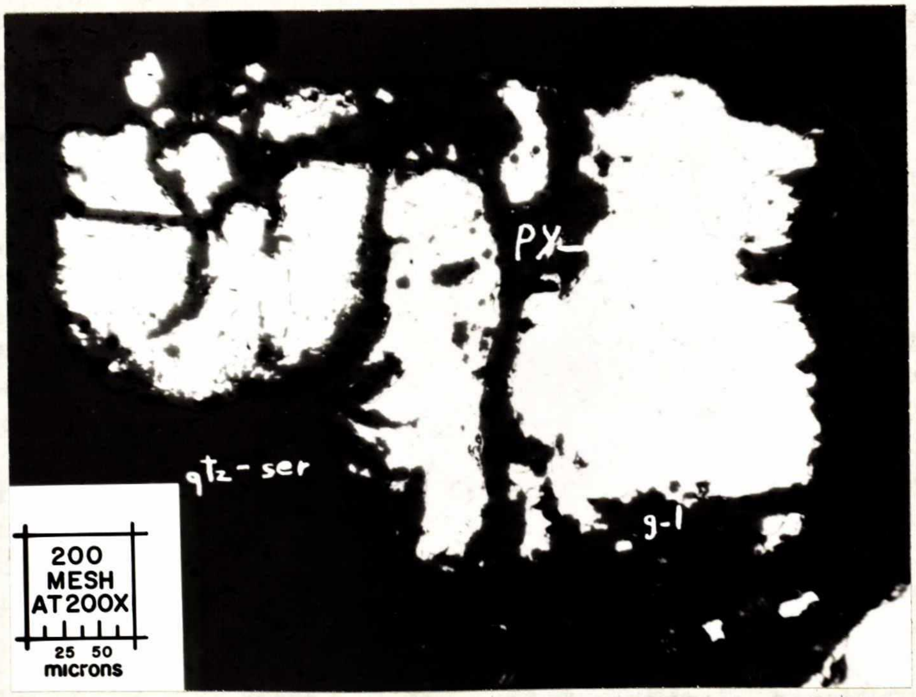

Figure 10. Alteration product (g-1) surrounds and penetrates a fractured crystal of pyrite (py) in a quartz-sericite grain (qtz-ser). 33-week residue.

DISCUSSION AND CONCLUSIONS

Microscopic study of polished sections of the 19-week and 33-week residues and examination of alpha track autoradiographs of the polished sections show that the extraction of uranium and of iron in leach test No. 10 is considerably greater than in test No. 6. Of the four radioactive minerals identified in the leach feed samples, namely brannerite, uraninite, monazite, and coffinite, the former two appear to have been completely altered and the latter two appear to have remained unchanged in the residues. The radioactive particles in both residues show no evidence of residual uraninite or brannerite, nor is there any indication of a differential leaching effect depending on the position of the radioactive particle in the grain of ore. It appears therefore, that the bacterial leaching solution has completely penetrated the grains of ore in both samples.

Chemical analyses of the products of the leaching tests (Table 1) indicate that in test No. 10 the maximum extraction of uranium has been achieved after 19 weeks whereas the extraction of iron and titanium continues beyond this point. On the basis of this data it can be concluded that the amount of uranium (and of iron and titanium) extracted by the bacterial leaching is a function of both grain size and time.

The apparent absence of uraninite in the residues may be due to (a) complete dissolution or (b) dissolution of most of the exposed uraninite and the oxidation of the remainder to uranic oxide, UO_3, which is amorphous. Brannerite too has apparently dissolved or decomposed since its presence could not be confirmed even after 19 weeks. Since brannerite is commonly intergrown with anatase or rutile in the ore conglomerate, the occurrence of radioactivity in leach residue grains which contain anatase or rutile strongly suggests that these grains originally contained brannerite. Although X-ray diffraction patterns of these grains do not show brannerite lines it is possible that either too small a proportion of residual brannerite remains therein to permit its detection or that the grains contain an amorphous uranium compound derived from brannerite.

Monazite appears to be unaffected by the leach solutions. It is doubtful whether the uranium silicate coffinite has been affected but it is so scarce in the leach feed that its apparent absence in the residues leaves this question open. The uranium appears to have been removed from the hydrocarbon thucholite.

Pyrite is the main sulphide mineral present in the leach feed and appears to have been the most affected by the leach solutions. Pitting occurs around the few pyrrhotite grains observed in the residues. The jagged edges of such grains indicates that particles of pyrrhotite have broken away during the polishing procedure. If a residue from the leaching solution had been pitted out the edges of the pyrrhotite grains would appear rounded. There are no residual rims or pitted zones around grains of chalcopyrite or galena showing that they were not affected by the leach solutions.

The leaching solution appears to have attacked the outer surfaces of all pyrite particles, entered and enlarged fractures and cavities and left behind a layer of soft grey material. This layer is several times thicker in the 31-week residue than in the 19-week residue indicating the leach solution is slowly dissolving the pyrite particles. Chemical analyses indicate the loss of iron from the 33-week residue is approximately four times as great as from the 19-week residue. X-ray diffraction analysis indicates that the soft grey residue around the pyrite particles is amorphous.

REFERENCES

1. S.M. Roscoe and H.R. Steacy, "On the Geology and Radioactive Deposits of the Blind River Region", Proceedings of the Second United Nations International Conference on the Peaceful Uses of Atomic Energy, P/222, 2, 475-483, United Nations, Geneva (1958).