

## **Specimen TK650 431 - Ferruginised Pyritic Cupriferous Quartz-Muscovite Rock**

W.R.Taylor, Mineralogical Consultant

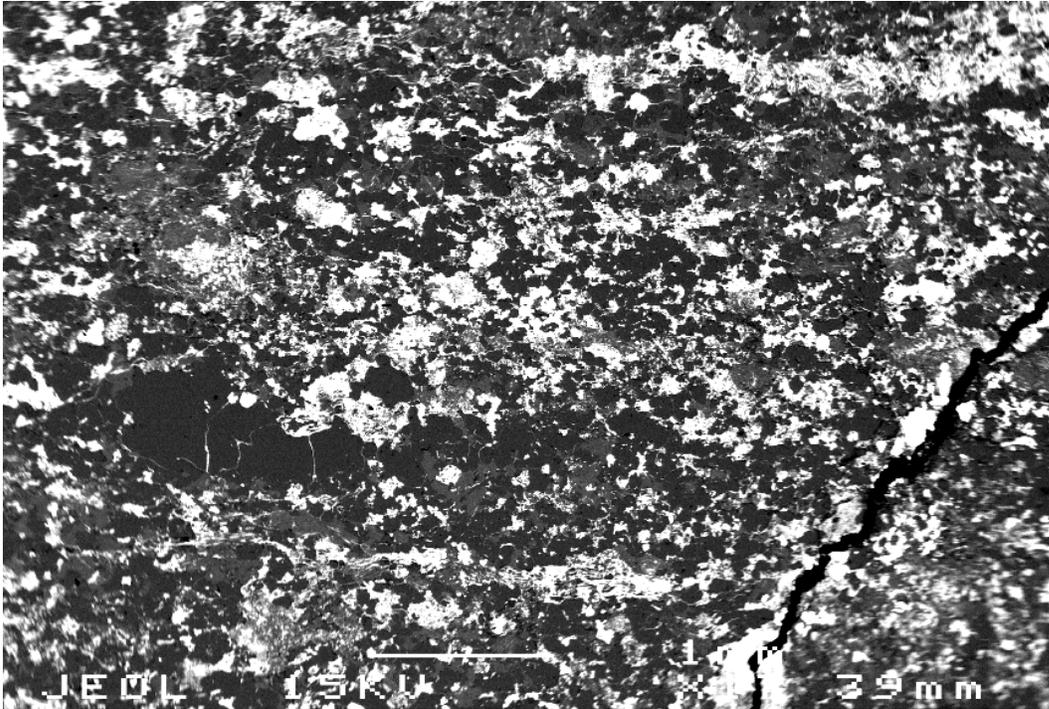
19-Aug-2010

A small interval (several cm) of drill core from hole TWDDH001(ex. Atom Energy Ltd, 2001, Cleo Prospect) was provided for petrographic assessment. In hand specimen, the sample appears to be an altered, sheared, ferruginised, quartz-mica rock; it is characterised by fine quartz banding of 0.25 to 1 mm thickness with some quartz occupying lenticular zones up to 3mm across. Under the binocular microscope crude compositional layering is evident; the layers are composed of colourless, fractured quartz or dark Fe-stained quartz alternating with other layers rich in hematite and/or limonite, white mica, and soft white to green-coloured ('copper-stained') clays. Numerous black, opaque grains having a bluish tarnish are embedded in the hematite/limonite and clay layers. White mica may be locally abundant and fractures are hematite-stained. Occasional relict bands of fine pyrite up to ~0.4 mm thick and rare pyrite masses up to 1 mm across are present in association with white clay masses and black grains.

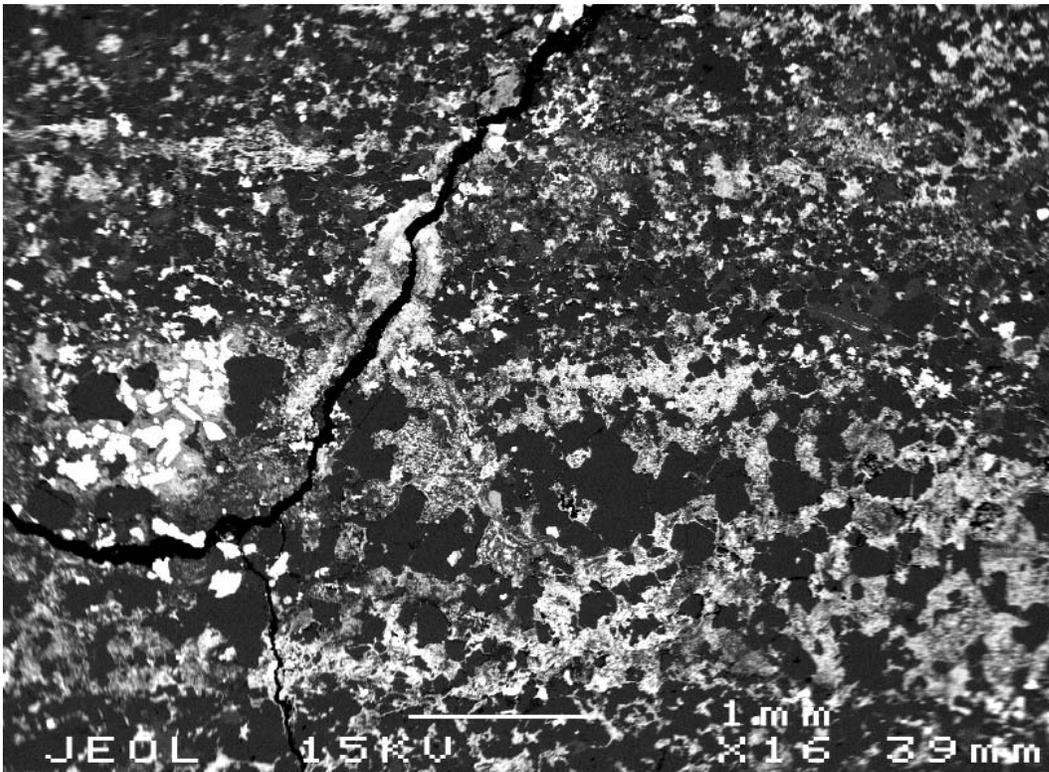
A section was prepared and examined under the SEM. The section was polished under kerosene to prevent loss of any water soluble minerals. The banded nature of the rock is apparent under the SEM. The compositional bands or layers consist of variable proportions of quartz, Fe-oxide/hydroxide, covellite (CuS; the black mineral with the blue tarnish seen in hand specimen), Fe-bearing illite, and muscovite (Figs. 1,2; Table 1); grain-sizes may vary between the bands and quartz crystals may be relatively coarse (~0.5 mm) in some bands (Fig. 2).

The Fe-oxide/hydroxide appears to consist of both hematite and goethite but their relative proportions cannot be determined under the SEM; XRD analysis would be required to determine exact proportions. Nevertheless, the Fe-oxide/hydroxides are clearly an oxidation product of former sulphide minerals and occasional relict pyrite and chalcopyrite are found as inclusions in this material. In some cases former muscovite has been partially or extensively replaced by Fe-oxide/hydroxide, particularly along cleavage planes, giving rise to mica pseudomorphs (Fig. 3).

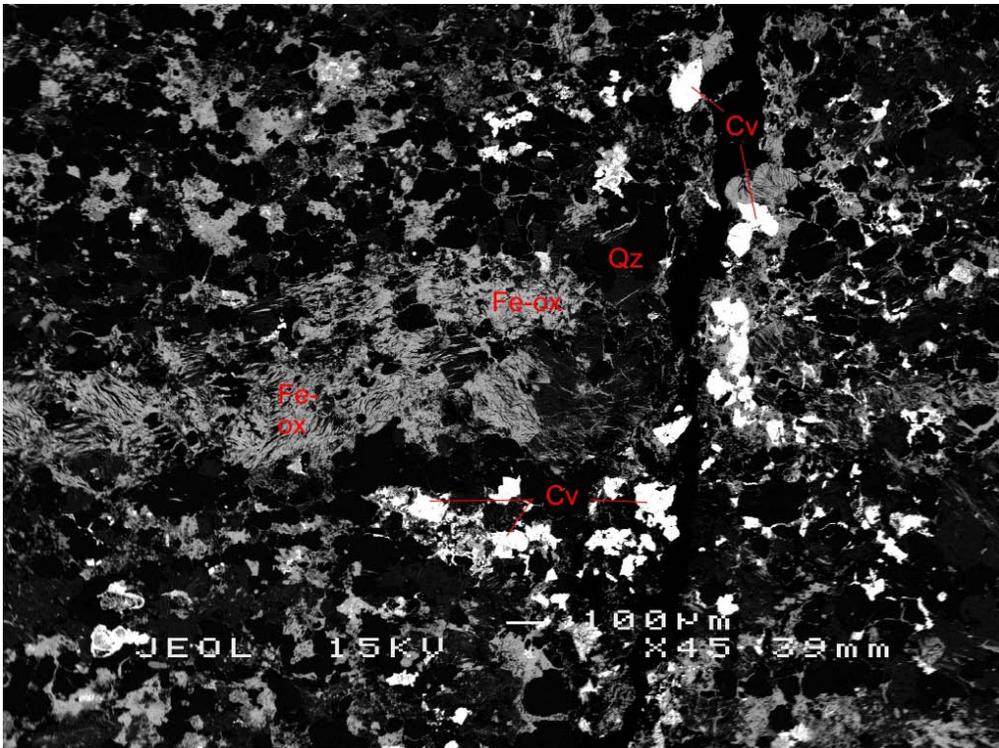
Covellite is commonly associated with Fe-oxide/hydroxide and occurs as ragged crystals about 100 microns in size and as aggregates of crystals (Figs 2-4); the covellite may contain inclusions of chalcopyrite. Both covellite and Fe-oxide/hydroxide line late fracture zones in the rock (Figs.2,4). Rare galena occurs as 10 micron inclusions in quartz. No uranium minerals were found during SEM investigation.



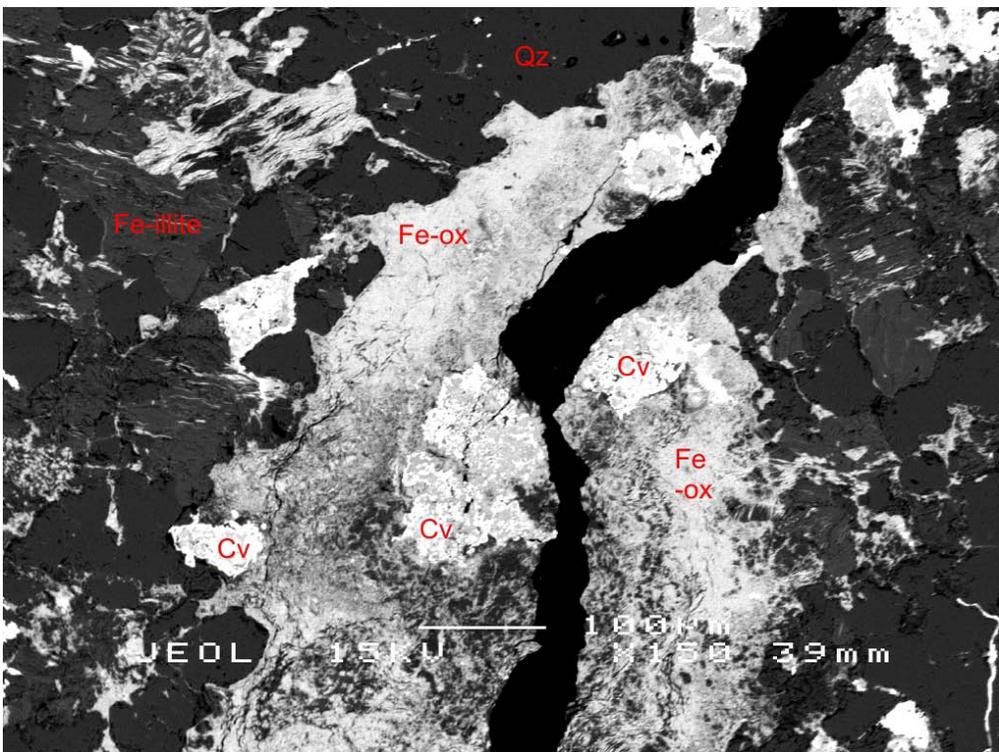
**Fig. 1** BSE image showing crude banding made up of Fe-oxide/hydroxide and covellite (light grey/white), quartz (black) and muscovite/illite (grey); note the late fracture at left; scale bar is 1 mm.



**Fig.2** BSE Photomicrograph showing compositional/textural banding; black = quartz; dark grey = illite/muscovite; light grey = Fe-oxide/hydroxide; white = covellite.



**Fig.3** BSE image showing Fe-oxide/hydroxide (Fe-ox) pseudomorphs after muscovite and the distribution of covellite grains (Cv; white); black grains are quartz.



**Fig.4** BSE image showing intergrown Fe-oxide/hydroxide (Fe-ox) and covellite (Cv) adjacent to a late fracture. The matrix is composed of Fe-illite, quartz and oxide/hydroxide (Fe-ox) pseudomorphs after muscovite.

Table 1. Analysis of Muscovite and Illite

Oxides	Muscovite	Fe-illite
SiO <sub>2</sub>	45.98	51.33
TiO <sub>2</sub>	bdl	bdl
Al <sub>2</sub> O <sub>3</sub>	34.07	24.44
FeO	2.49	9.52
MnO	bdl	bdl
MgO	3.91	2.39
CaO	bdl	bdl
Na <sub>2</sub> O	bdl	bdl
K <sub>2</sub> O	10.85	5.74
Total	97.30	93.42

The bulk rock composition, obtained from area scans (Table 2), is consistent with 2-3% covellite, 15-20% Fe oxide/hydroxide, 15-30% muscovite/illite, and 40-50% quartz.

Table 2. Bulk Rock Scans

Oxides	Area Scan #1	Area Scan #2
SiO <sub>2</sub>	62.27	67.81
TiO <sub>2</sub>	0.32	0.19
Al <sub>2</sub> O <sub>3</sub>	9.58	9.49
FeO	20.43	15.02
MgO	0.87	1.02
CaO	bdl	bdl
CuO	2.31	1.79
Na <sub>2</sub> O	bdl	0.31
K <sub>2</sub> O	1.36	2.22
UO <sub>2</sub>	bdl	bdl
P <sub>2</sub> O <sub>5</sub>	bdl	bdl
SO <sub>3</sub>	2.39	1.80
Total	98.90	98.72

**Discussion.** Covellite is a secondary copper sulphide mineral that, in this case, formed by oxidation of original chalcopyrite. The Fe-oxide/hydroxide is an oxidation product after former pyrite and chalcopyrite. The alteration of former sulphides is most likely due to late penetration of oxidised meteoric waters along fracture/fault zones in the rock succession. The rock is best described as an ferruginised (i.e. oxidised), pyritic, cupriferous, quartz-muscovite rock; it represents a interval of copper mineralisation within the drill core and is possibly associated with a small shear zone. The bulk rock composition does not provide a clear guide to the original host rock but a granitoid, felsic tuff or pelitic sediment are all possible. The host, however, was extensively altered and overprinted by hydrothermal fluids which deposited pyrite and chalcopyrite.

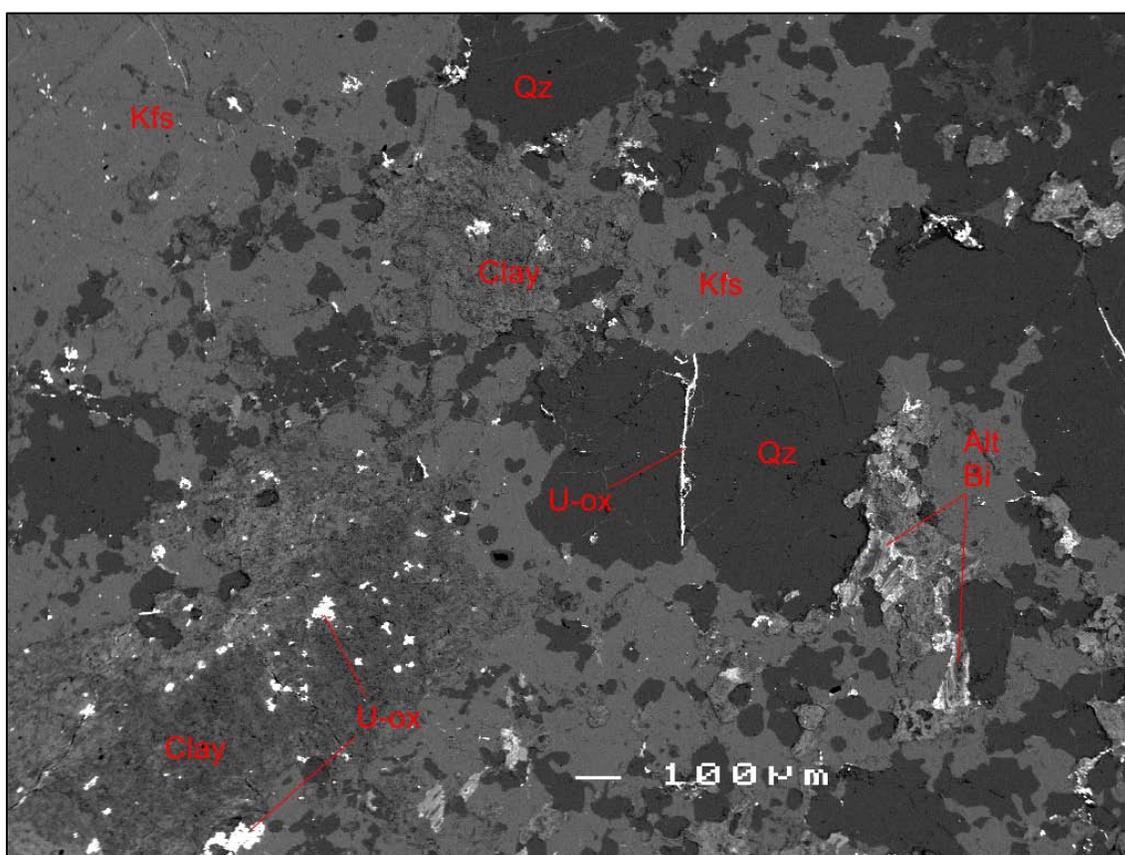
## Specimen TK650 429 Altered Uraniferous Granitoid

W.R. Taylor, Mineralogical Consultant

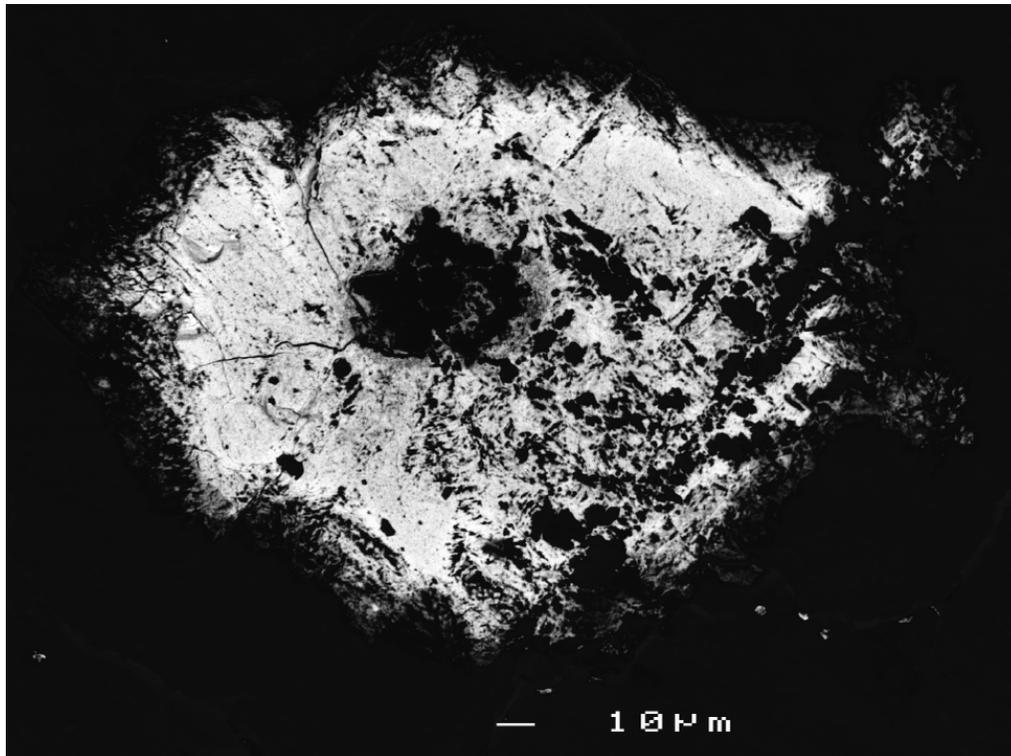
20-Aug-2010

A sample of drill core (ex. Total Mining Ltd, 1986) was provided. In hand specimen the rock has the appearance of a strongly altered granitoid. The rock is composed largely of pink K-feldspar, clear to grey-coloured quartz, patches of fine black biotite and wispy chlorite; large 0.5-3 mm sized blob-like masses of grey-green clay are common, as are hematite dustings. Fractures cross-cutting the rock are typically stained yellow and contain hematite, white clays and greenish-coloured clays. Along the fractures distinct redox boundaries can be identified between the greenish-coloured clays and hematite-dusted white clays or yellow-stained clays.

A polished section was prepared under kerosene to prevent loss of any water soluble minerals and the section was examined under the SEM. Illustrative back-scattered electron (BSE) photomicrographs are provided (Figs 1-3). The rock is dominantly composed of K-feldspar and quartz both of which have ragged grain boundary outlines suggesting they have been hydrothermally recrystallized; igneous microtextures are not preserved. The K-feldspar and quartz are associated with altered biotite and clays; the latter in some cases appear to replace former primary aluminosilicate minerals (Fig.1) or form blob-like masses.



**Fig.1.** BSE image of sample 429 showing it consists of K-feldspar (Kfs; light grey); quartz (Qz, dark grey); altered, uranium-oxide-replaced biotite (Alt.Bi) and clay (grey mottled) some of which (lower left) appears to be rectangular in outline and is probably pseudomorphous after former plagioclase or other aluminosilicate mineral. Numerous scattered grains of impure uraninite and secondary gummite (U-ox, white) occur in the matrix and as fracture fillings.



**Fig.2** Mass of 'gummite' (secondary mixture of uranium oxides after uraninite; light grey) of ~150 microns size with a central core of bravoite (nickeliferous pyrite; grey) and quartz (black).

Impure uraninite and its secondary alteration product 'gummite' are common in the rock and occur in a number of sites: (a) as fracture fillings in quartz (Fig.1), (b) as scattered 5 to 150 micron sized grains in the matrix (Figs 1,2; Table 1), (c) as a replacement mineral along cleavage planes in altered biotite (Table 3), and (d) as intricate intergrowths with clay mineral masses (Fig.3; Table 3). Some larger uranium oxide grains are cored by bravoite (nickeliferous pyrite; Fig.2. Table 2). The clay mineral in the blob-like masses (Fig.3) is a smectite containing both Ca and Na and therefore is probably derived from former plagioclase (Table 3).

Table 1. Analysis of Secondary Uranium Oxide

Oxides	Gummite Fig.2
SiO <sub>2</sub>	2.16
TiO <sub>2</sub>	0.58
Al <sub>2</sub> O <sub>3</sub>	1.15
FeO	bdl
MgO	0.36
CaO	1.10
Na <sub>2</sub> O	0.56
K <sub>2</sub> O	bdl
UO <sub>2</sub>	85.52
PbO	bdl
P <sub>2</sub> O <sub>5</sub>	1.58
SO <sub>3</sub>	bdl
Total	89.12

Table 2. Analysis of Bravoite

Element%	Bravoite
S	52.3
Fe	41.1
Ni	3.9
Co	2.7
Total	100.0

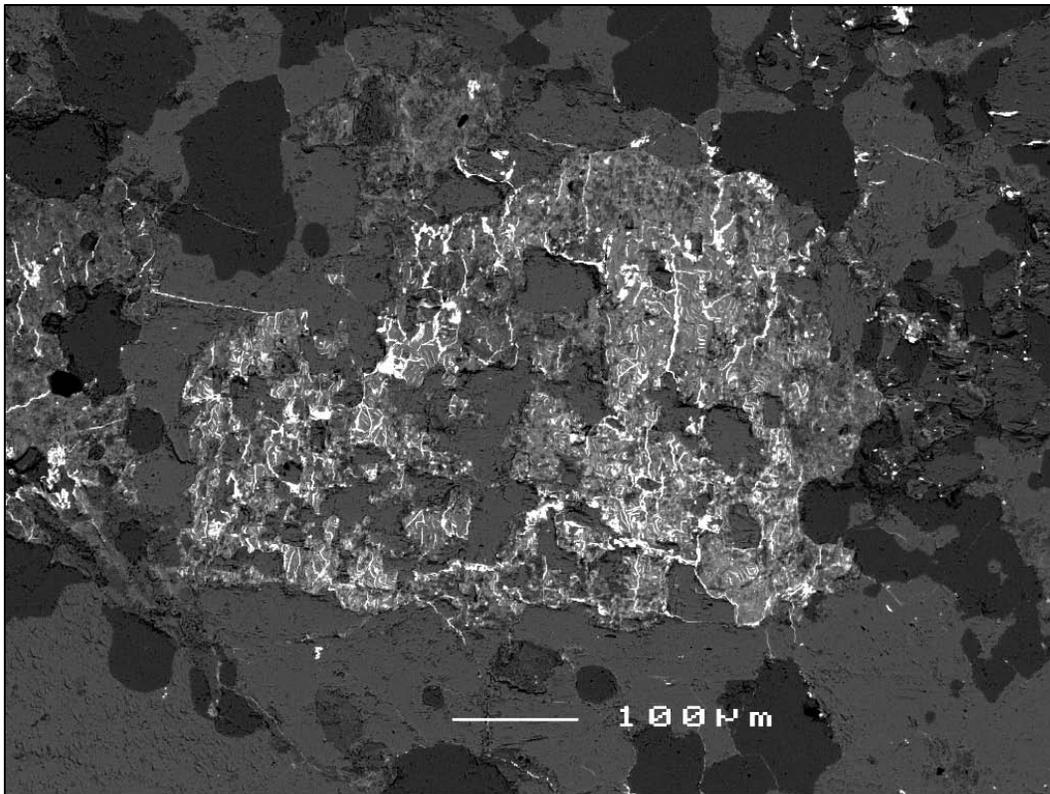
Table 3. Analyses of Altered Biotite and Clay Minerals

Oxide%	Altered Biotite Fig.1	U-replaced Clay after biotite Fig.1	Smectitic Clay Fig.3	Smectitic Clay Fig.3
SiO <sub>2</sub>	40.53	37.34	32.37	31.79
TiO <sub>2</sub>	bdl	bdl	0.79	2.47
Al <sub>2</sub> O <sub>3</sub>	20.90	22.07	31.18	28.90
FeO	3.90	6.21	10.46	11.10
MgO	16.36	12.21	3.23	3.54
CaO	bdl	bdl	1.20	1.22
Na <sub>2</sub> O	bdl	bdl	1.32	1.49
K <sub>2</sub> O	4.24	0.42	bdl	bdl
P <sub>2</sub> O <sub>5</sub>	bdl	bdl	bdl	bdl
UO <sub>2</sub>	1.43	8.19	bdl	bdl
Total	87.36	86.44	80.55	80.51

Table 4. Area Scans

Oxide%	Area Scan 429#1	Area Scan 429#2
SiO <sub>2</sub>	70.27	68.11
TiO <sub>2</sub>	bdl	bdl
Al <sub>2</sub> O <sub>3</sub>	15.06	16.27
FeO	1.38	1.66
MgO	2.10	3.26
CaO	bdl	bdl
Na <sub>2</sub> O	0.39	0.42
K <sub>2</sub> O	9.33	8.78
UO <sub>2</sub>	0.80	1.26
P <sub>2</sub> O <sub>5</sub>	bdl	bdl
SO <sub>3</sub>	bdl	bdl
Total	99.33	99.76

bdl= below-detection-limit.



**Fig.3** Smectitic clay mass (grey, mottled) with veins and numerous fine inclusions of impure uraninite and gummite (white). Associated minerals are quartz (dark grey-black) and K-feldspar (grey; dominant).

The bulk rock composition, obtained from area scans (Table 4), is consistent with approx. 45-50% of K-feldspar, 10% altered biotite, 10% clays, 30-35% quartz and 1 % uraninite. The rock has very low CaO and low Na<sub>2</sub>O contents consistent with the absence of plagioclase; any original plagioclase present in the granitoid appears to have been altered to clay minerals with all CaO lost from the system.

The inferred paragenetic sequence is as follows: the initial (highest-T) hydrothermal alteration resulted in formation of bravoite together with breakdown of plagioclase, alteration of biotite and recrystallization of quartz and K-feldspar. This was followed by precipitation of uraninite on bravoite nuclei and on cleavage planes in altered biotite. The last stage (lowest-T) involved the oxidation, alteration and redistribution of uraninite to form secondary uranium oxides ('gummite'), which filled fractures and formed intergrowths with clay minerals. Hematite also formed at this stage; the late oxidation is most likely associated with an influx of oxidised meteoric waters.

The rock is best described as a hydrothermally-altered, uranium-mineralized granitoid.