

# Mineralogical Report on Sample TN211040: Arkose

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A 30cm drill core sample of an arkosic sedimentary rock from the Carboniferous Mount Eclipse Sandstone of the Ngalia Basin (NT) was examined under the binocular microscope and the scanning electron microscope. Under the binocular microscope the core material is a coarse to medium-grained arkose dominated by detrital quartz, pink K-feldspar and muscovite with lesser biotite and chlorite. The clasts are set in a thin calcite or clay matrix which is absent in places resulting in areas of high porosity. Pyritic shale "rip-up" clasts up to several cm size are common in the lower two-thirds of the core sample; in the upper third of the core, thin stringers of carbonaceous material are common together with biotite/chlorite giving the rock a dark, layered appearance. Measurements with a portable XRF indicate the dark upper part of the core contains around 200 ppm U whereas the U content of the lower arkose is below detection.

The Mount Eclipse Sandstone is host to uraninite and carnotite mineralisation at the Bigirlyi Deposit located to the northwest of the drill hole site. According to Fidler et al (1990) eight different units can be recognised in the Mount Eclipse Sandstone: "The principal host for uranium mineralisation at Bigirlyi is a 20 to 200 m thick feldspathic sandstone which contains shale clasts, abundant carbonaceous debris, pyrite and, rarely, pebbles. The matrix is composed of chlorite and fine mica with carbonate cement. Carbonaceous material is present as disseminated flecks of graphite or rare coaly stringers. Interbedded shale bands are similar in appearance to the shale clasts and are also carbonaceous, graphitic and pyritic." This description by Fidler et al. is similar in all respects to the arkose described here.

Polished sections of arkose from both the dark upper core and the lighter lower core were prepared and examined under the SEM. Illustrative backscattered electron imagery is provided in Figs 1 to 6 (dark arkose) and Figs 7 to 10 (light arkose), and selected mineral analyses are given in Tables 1 and 2. Area scans are provided in Table 3.

The arkose is dominated by ~0.1-1.0 mm sized angular clasts of quartz and K-feldspar with common detrital muscovite, biotite and chlorite of platy form (Fig.1). Detrital grains of lesser abundance include apatite, zircon, almandine garnet and monazite. The intergranular cement is either calcite or kaolinitic clay. The dark arkose contains common stringers of carbonaceous matter in which inclusions of pyrite are embedded. The pyrite occurs both as framboids (~1-10 microns size), often in clusters, and as larger more euhedral, and sometimes composite, crystals (Figs 2-4). Pyrite also occurs as fine inclusions in altered biotite and in chlorite where it decorates cleavage planes (Fig.3). The pyrite is normal Fe-pyrite in composition. The carbonaceous stringers are typically bordered by platy biotite, altered biotite (i.e. K-deficient biotite; Table 1), chlorite and/or muscovite (Figs 3,4).

In the dark arkose, uranium occurs as a solid-solution component of altered zircon (Figs 5a,b; Table 2). The altered zircons are zoned with uraniferous overgrowths and internal zones rich in uranium (UO<sub>2</sub> contents may exceed 30%) but remnant zones of normal zircon are also present. The U-rich zones are characterised by high P<sub>2</sub>O<sub>5</sub> contents as well as other impurity elements so that some compositions are best described as (Fe,Ca)-U-Zr-P silicate (Table 2). The altered zircon grains have skeletal forms and appear to be aggregates of several smaller crystals, or perhaps crystal fragments, having different orientations. The grains typically but not exclusively occur in proximity to

carbonaceous stringers and some contain inclusions of carbonaceous matter. One U-rich altered zircon, associated with pyrite, was found in the light arkose (Fig.10). No other uranium-bearing minerals have been identified in the rock and no vanadium-bearing minerals have been found.

The light arkose is mineralogically similar to the dark arkose (Fig.9) except for an absence of carbonaceous matter and a lower mica content. The shale clasts typically consist of a pyritic core surrounded by a fine-grained silicate-rich margin composed of a mixture of quartz, muscovite, altered biotite/chlorite, pyrite and clay minerals.

Table.1 Selected Analyses of Silicate Minerals

	Biotite Fig.3	Altered- Biotite Fig.3	Fe- Chlorite Fig. 4	Chlorite Fig.2	Muscovite Fig.2	K- Feldspar Fig.2
SiO <sub>2</sub>	36.03	35.42	26.70	32.60	49.78	64.64
TiO <sub>2</sub>	4.03	0.52	bdl	bdl	bdl	bdl
Al <sub>2</sub> O <sub>3</sub>	16.32	24.57	20.19	19.86	29.97	18.51
FeO	21.21	18.67	30.14	9.94	3.67	bdl
MgO	9.54	9.83	11.36	27.19	1.44	bdl
CaO	bdl	bdl	bdl	bdl	bdl	bdl
Na <sub>2</sub> O	bdl	bdl	bdl	bdl	bdl	0.62
K <sub>2</sub> O	9.20	7.92	0.15	0.40	10.92	16.18
Cl	0.33	bdl	bdl	bdl	bdl	bdl
Total	96.66	96.93	88.54	89.99	95.78	99.95

bdl = below-detection-limit

Table 2. Analyses of Altered Uraniferous Zircon and Unaltered Zircon

	Altered Zircon Fig.10	Altered Zircon Fig. 5b #2	Zircon Fig. 5b #1	Altered Zircon Fig.5a #3	Altered Zircon Fig.5a #2	Altered Zircon Fig.5a #1	U-Zr Silicate Fig. 2
SiO <sub>2</sub>	16.20	18.68	32.93	19.9	20.62	21.81	25.88
TiO <sub>2</sub>	bdl	bdl	bdl	0.78	0.75	0.49	0.57
Al <sub>2</sub> O <sub>3</sub>	0.80	0.45	bdl	4.55	0.55	0.32	9.34
FeO	3.08	0.50	bdl	2.75	1.06	0.68	6.31
MgO	bdl	0.34	bdl	1.22	bdl	bdl	8.68
CaO	1.63	2.72	0.30	2.58	2.13	1.39	2.08
P <sub>2</sub> O <sub>5</sub>	12.36	6.55	bdl	7.10	4.68	3.68	4.89
UO <sub>2</sub>	21.38	31.16	bdl	33.14	13.10	15.78	19.35
ZrO <sub>2</sub>	35.66	37.12	66.48	24.72	55.13	53.76	14.64
Total	91.11	97.52	99.71	96.74	98.02	97.91	91.74

Area scans provided in Table 3 give a guide to the bulk composition of the rock and indicate the dark arkose, outside of carbonaceous zones, is composed of ~50-55% quartz, ~25% K-feldspar and muscovite, ~15-20% biotite and chlorite, ~3% calcite and ~1% pyrite. An area scan of a carbonaceous band indicates it is composed of >90% carbonaceous matter with a few percent each of pyrite and chlorite (note carbon cannot be analysed directly by the SEM and the value is obtained from the

total by difference); the high chlorine content (2.7 %) of the organic material is unusual, for example, chlorine contents in low rank coals typically do not exceed 1% Cl. A scan of the silicate-dominant matrix of a shale clast in Fig.7 indicates it is composed of ~15-20% quartz, ~35-40% K-feldspar and muscovite, ~25% biotite and chlorite, ~10% kaolinitic clay and ~7% pyrite. In all cases UO<sub>2</sub> levels are below detection limits.

Table 3. Area Scans

	Area scan #1	Area scan #2	Organic-rich area	Shale clast Fig.7
SiO <sub>2</sub>	75.35	71.25	1.89	52.60
TiO <sub>2</sub>	0.51	0.81	bdl	bdl
Al <sub>2</sub> O <sub>3</sub>	10.84	11.79	1.12	17.92
FeO	4.53	5.78	0.83	10.31
MgO	2.69	3.97	0.44	4.60
CaO	1.52	1.84	bdl	bdl
Na <sub>2</sub> O	bdl	bdl	bdl	bdl
K <sub>2</sub> O	3.39	3.23	bdl	5.41
P <sub>2</sub> O <sub>5</sub>	bdl	bdl	bdl	bdl
SO <sub>3</sub>	0.87	1.44	2.17	8.81
Cl	0.07	bdl	2.74	bdl
Total	99.77	100.11	9.19	99.65

Dark Arkose SEM Images:

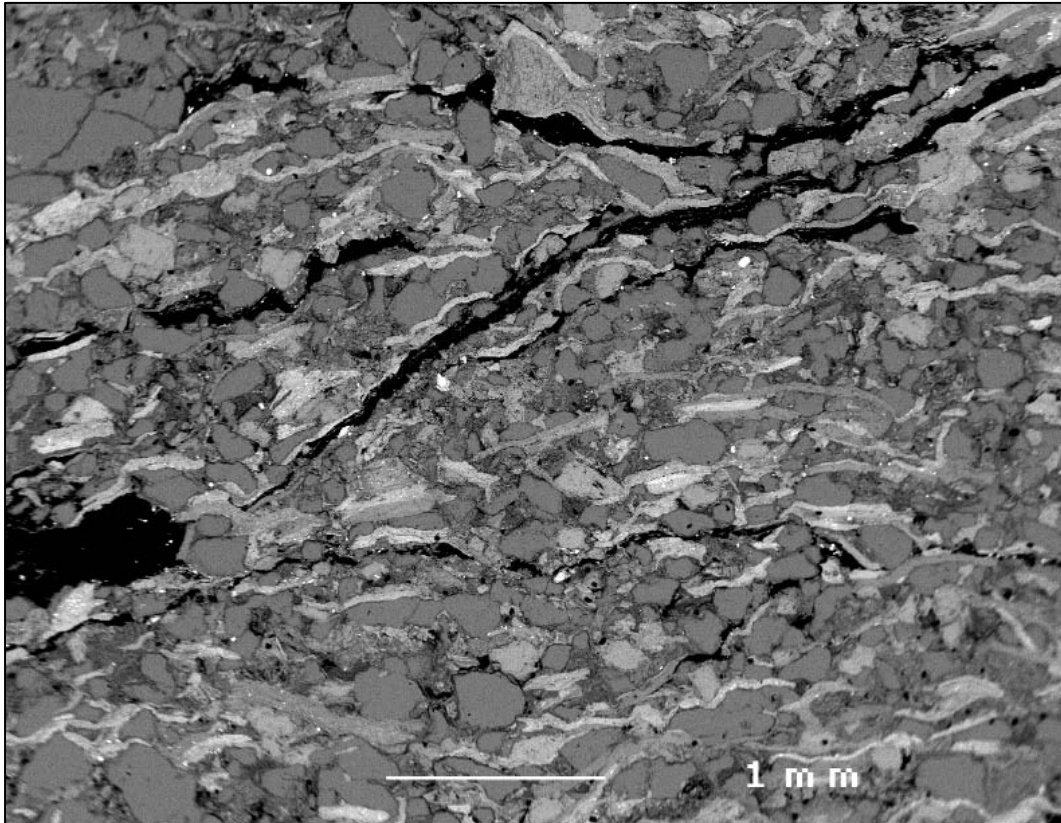


Fig.1. BSE image of showing ~0.1-1.0 mm sized clasts of quartz (dark grey) and K-feldspar (light grey) with interstitial platy micas, chlorite and clay. Black stringers and blobs are carbonaceous matter.

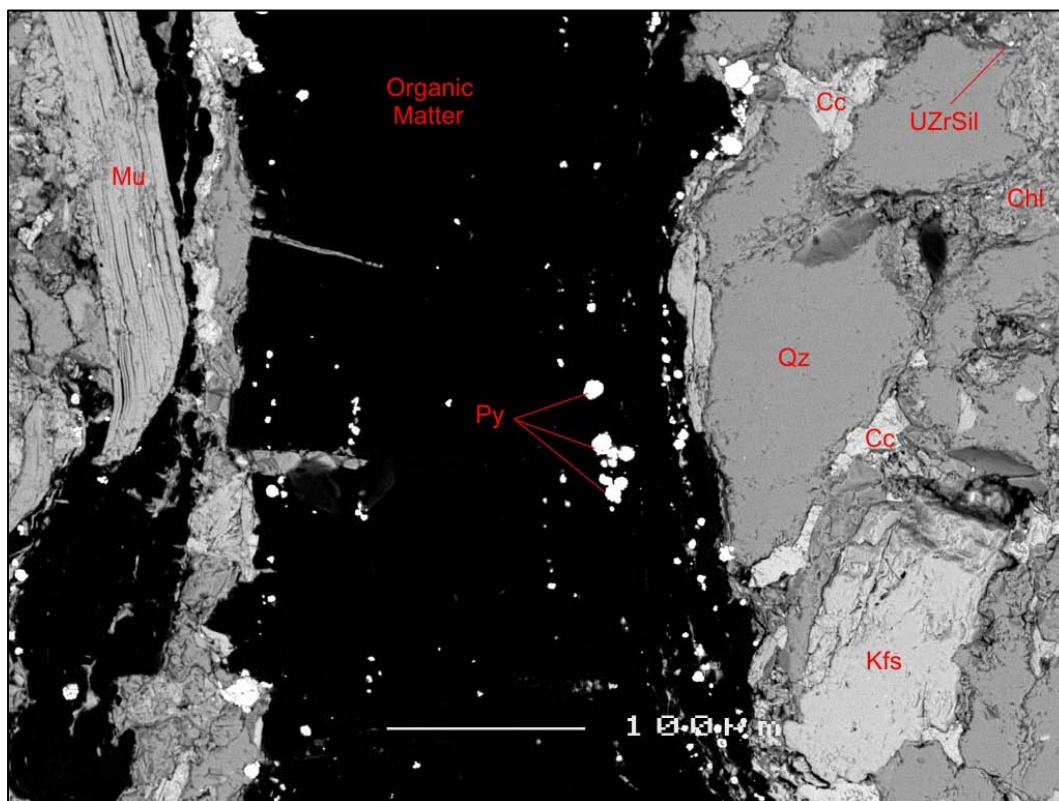


Fig.2. Detail of a carbonaceous stringer (black) showing inclusions of fine pyrite (Py). The stringer is bordered by quartz (Qz), K-feldspar(Kfs) and muscovite (Mu). A thin matrix of calcite (Cc) is present in places. A tiny crystal of U-Zr silicate (UZrSil) is located at upper right associated with chlorite (Chl).

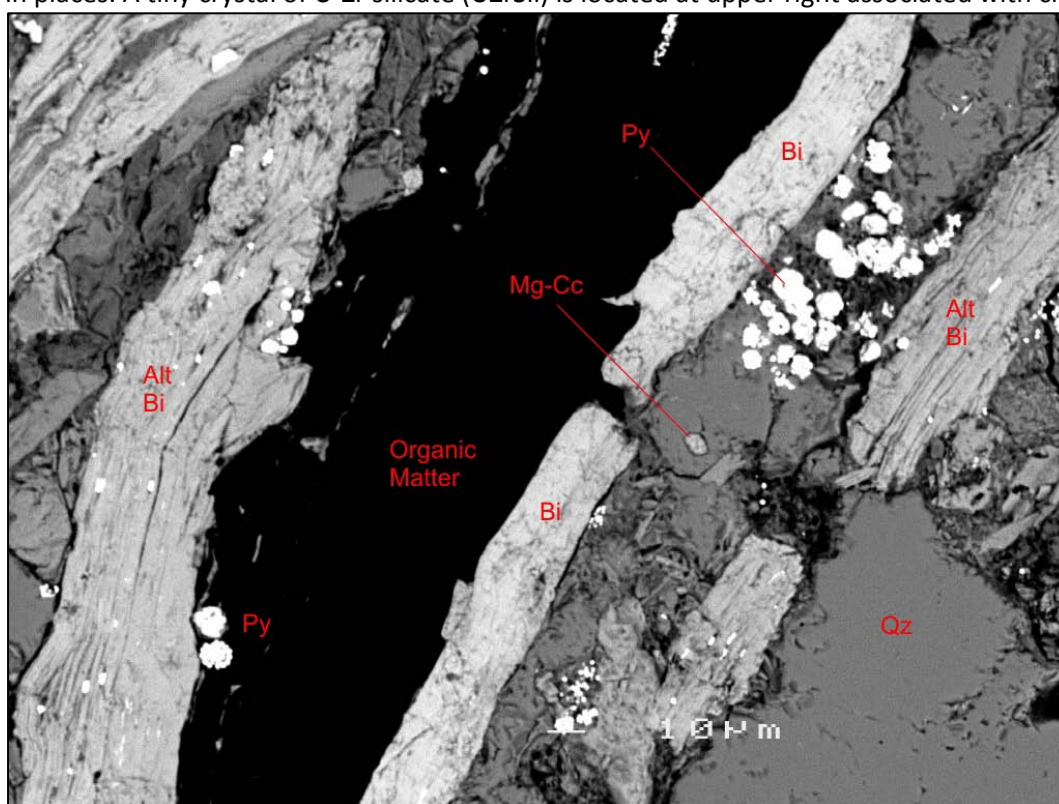


Fig.3. Detail of a carbonaceous stringer (black) which is bordered by plates of biotite (Bi) or altered biotite (Alt-Bi). Pyrite framboids (Py) occur as inclusions in the organic matter, on cleavage planes in mica and in intergranular spaces together with clay minerals. A small inclusion of magnesian calcite (Mg-Cc) occurs in quartz.

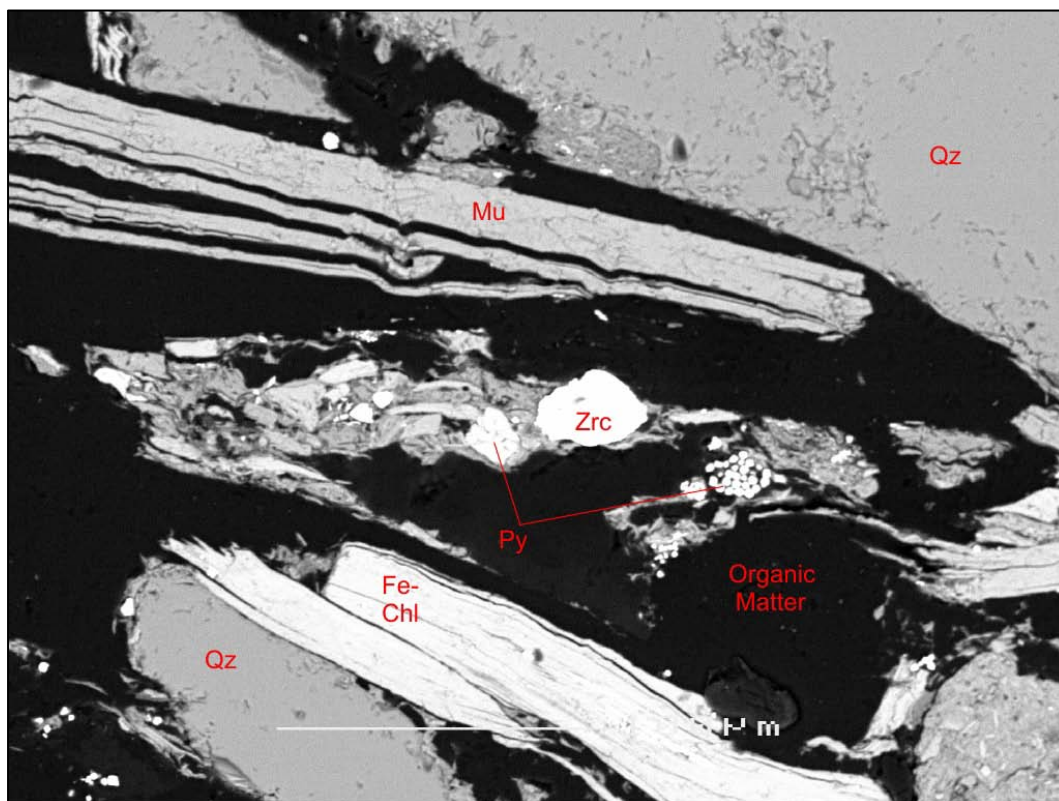
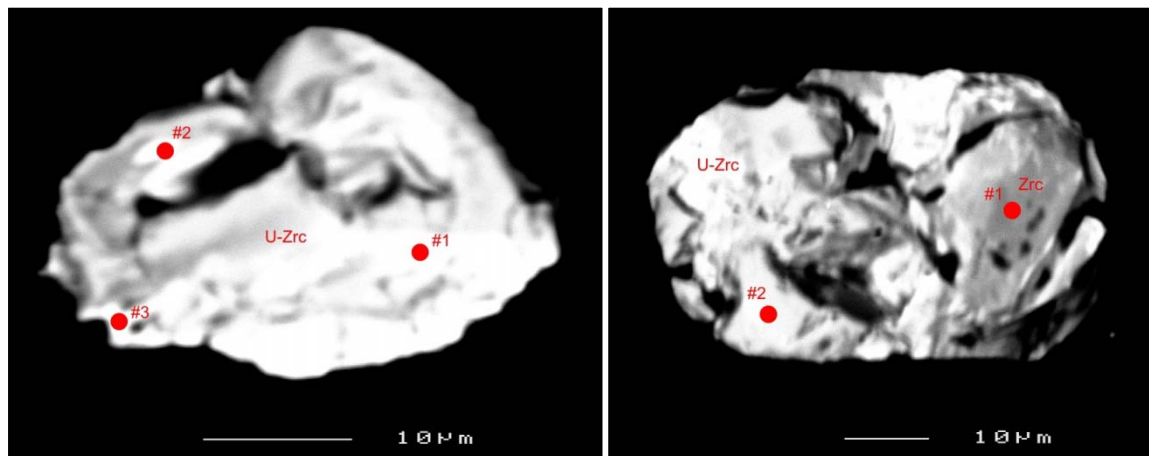
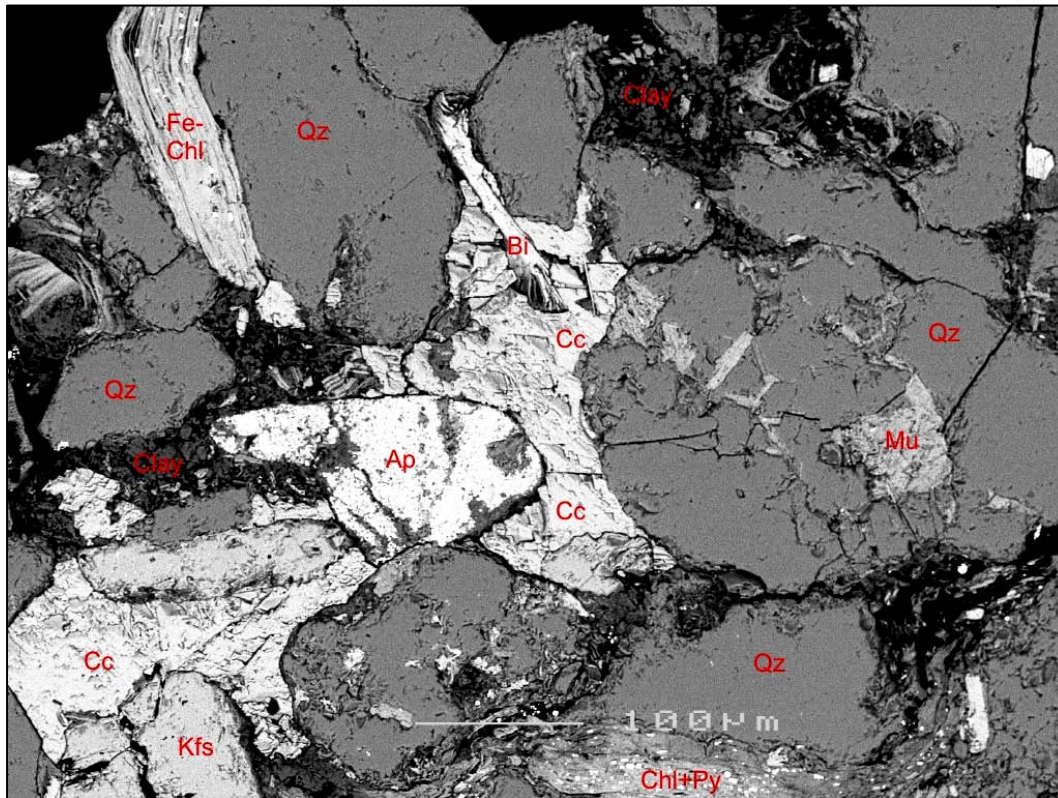


Fig.4. Detail of a carbonaceous stringer (black) bordered by muscovite (Mu) and Fe-chlorite (Fe-Chl). Pyrite framboids and larger crystals are associated with an altered zircon crystal (Zrc). Scale 100μm.



Figs.5a/5b. Detail of composite, zoned uraniferous zircon grains of 20-40 microns size. The zircons have skeletal forms and uraniferous overgrowths and internal zones (white under BSE imaging). The U-rich zones are characterised by high  $P_2O_5$  contents. The grains appear to be aggregates of several smaller crystals or crystal fragments with different orientations. Dark inclusions are carbonaceous matter. The zircon shown in Fig.5a (left) is the same grain as shown in Fig.4 centre. Analytical spots are identified for each grain (see Table 2). Analysis #1 in Fig.5b (grey area, right) is normal zircon.





Figs.6. Detail showing a detrital apatite grain (Ap, broken grain at centre), with clasts of quartz, K-feldspar, Fe-chlorite (with tiny pyrite inclusions), biotite and composite muscovite-quartz. The matrix is composed of either calcite (Cc) or clay minerals (Clay).

Light Arkose SEM Images:

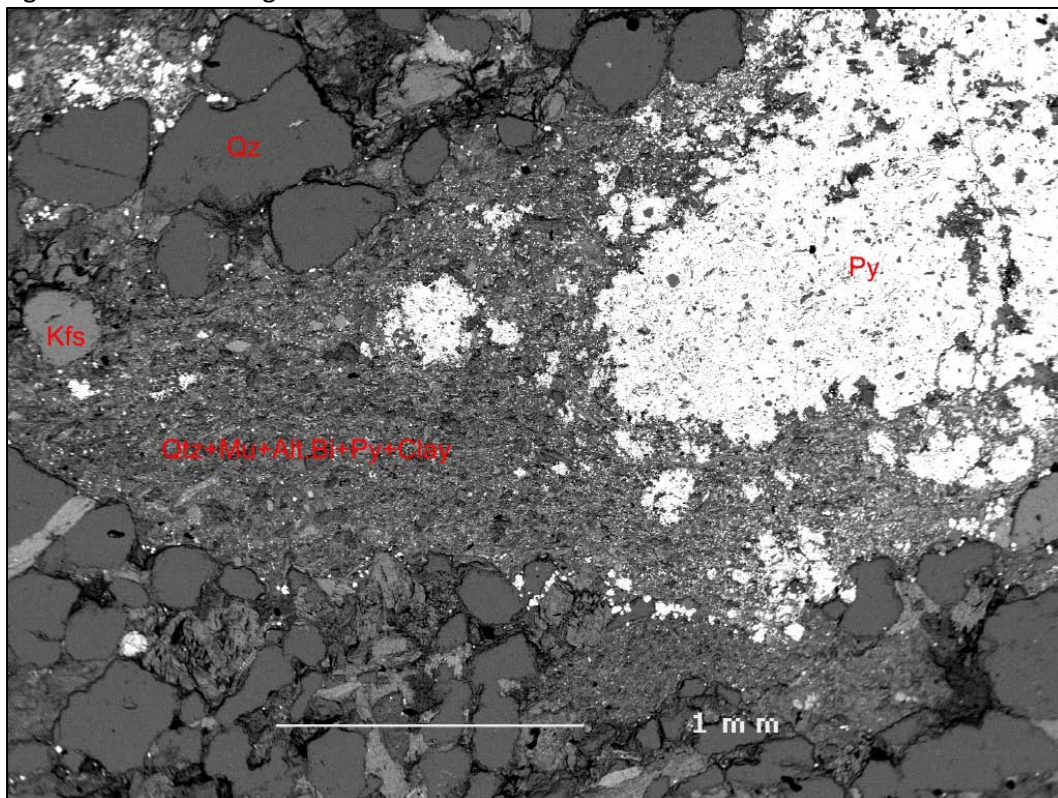


Fig.7. Detail of a pyritic shale clast showing a fine matrix composed of a mixture of quartz, muscovite, altered biotite/chlorite, pyrite and clay minerals. The clast core (upper right) is dominantly pyrite.



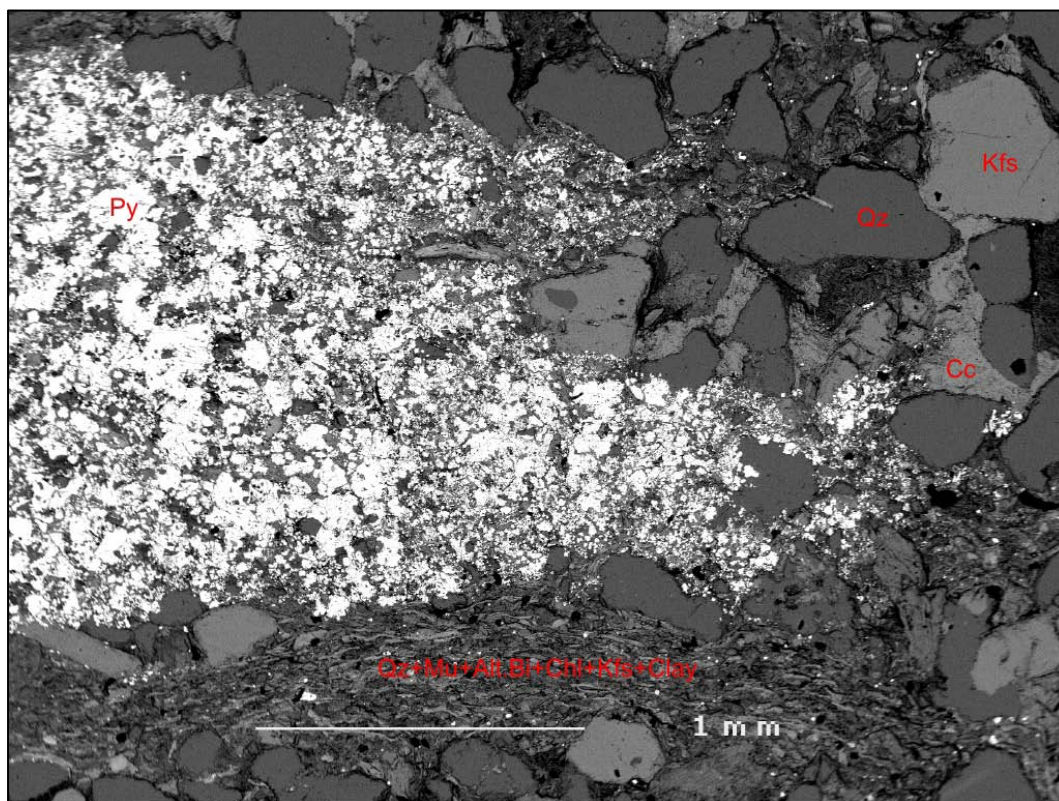


Fig.8. Another pyritic shale clast with a fine matrix and pyrite-rich core.

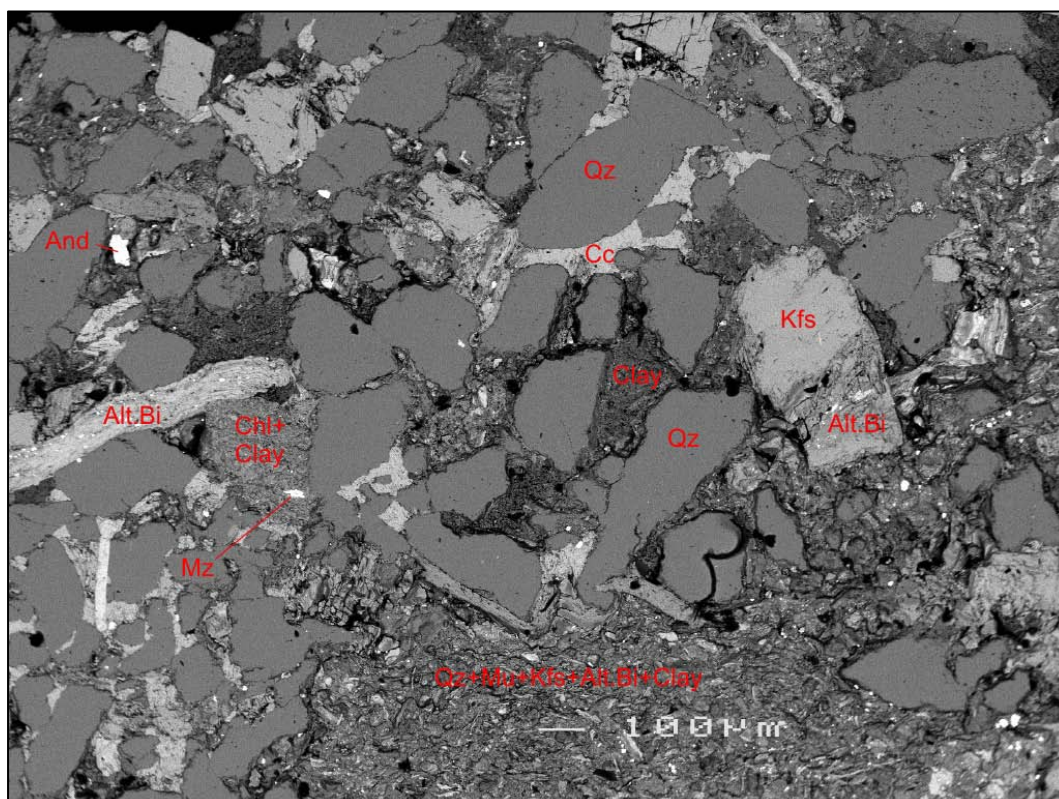


Fig.9. Detail of arkose showing angular quartz (Qz) and K-feldspar (Kfs) clasts of 0.1-0.5mm size together altered biotite plates (Alt-Bi), rare almandine garnet (And), and monazite (Mz; ~7% ThO<sub>2</sub> but no U content). The intergranular matrix is composed of either calcite (Cc) or clay minerals (Clay). A shale clast composed of fine minerals is shown at the bottom of the image.

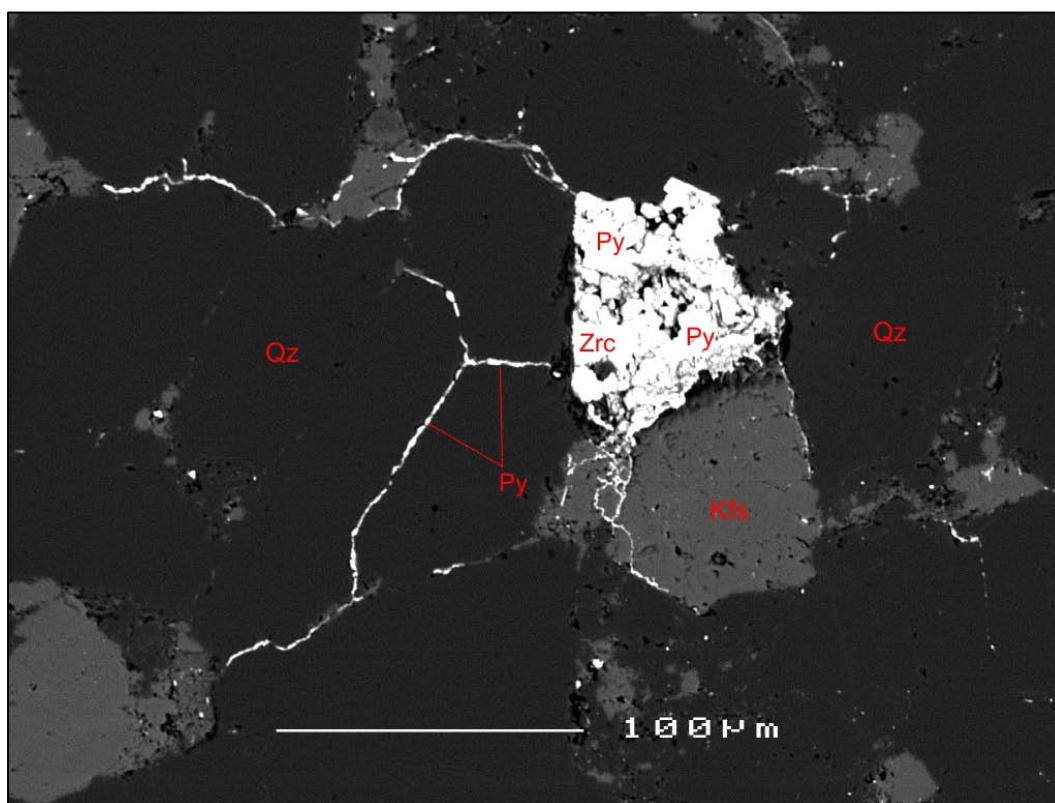


Fig.10. Composite grain of altered zircon and pyrite (white), with fine pyrite filling adjacent grain boundaries and fractures. The altered zircon is uraniferous (Table 2).

#### Conclusions:

The rock is best described as an arkose or arkosic sandstone. The detrital components of the arkose are essentially granitic debris. The rock is a little unusual in that it contains significant detrital biotite and altered biotite as well as chlorite, which is probably a chemical weathering product of original biotite. Most arkosic rocks do not contain biotite because of its susceptibility to weathering. In this case the presence of biotite indicates the sedimentary source material was derived from a proximal granitoid that was being rapidly eroded (presumably due to uplift associated with the latter part of the Alice Springs orogeny). The carbonaceous matter, pyrite and pyritic shale clasts suggests the depositional environment involved active microbial activity and anoxic conditions, perhaps associated with a series of lakes or lagoons.

The occurrence of uranium as a component of phosphorus-rich Zr silicate overgrowths on zircon ("altered zircon") is of interest. It appears that uranium and phosphorus released by chemical weathering is being sequestered during a process of zircon alteration. The highest concentrations of uraniferous altered zircons occur in association with carbonaceous matter and pyrite suggesting that a reducing environment is important in precipitating out the U-P-Zr silicate overgrowths. The overgrowths perhaps form by a process of zircon dissolution and replacement during diagenesis; the addition of U and P being from chemical breakdown of accessory granite minerals. Altered zircon may be an intermediate-stage storage site for uranium in granite-derived sediments from where it can be later remobilized.

#### Reference

Fidler RW, Pope GJ, Ivanac JF (1990) Biglryi Uranium deposit: In Hughes F E (Ed.), *Geology of the Mineral Deposits of Australia & Papua New Guinea*, AusIMM Monograph 14, vol2. pp 1135-1138.