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## Tracker Geoservices Pty Ltd

# Annual Report GR427 Florina Project

For the Period 30 July 2015 to 29 July 2016

RD Gee

31 August 2016

Target Commodities - Potash and Phosphate

Fergusson River 1:250 000 Sheet  
Fergusson River (5269) and Bowman (5268) 100 000 Sheets

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## Abstract

The Florina Potassium-Phosphate Project is based on the Ordovician Florina Formation in the Daly River Basin, which contains glauconite-rich sandstones. Glauconite is a potential source of potassium fertiliser with phosphate credits, suitable for local and national agricultural use. The project is centred on Florina Pastoral Station 70 km west of the regional town of Katherine in the Northern Territory.

Florina Formation consists of two glauconitic sandstones sandwiched between dolostones. The lower glauconitic sandstone (LGS) is 68 metres thick as determined by water bore drilling. Geological mapping indicates the LGS is mostly free of the overlying Cretaceous sandstone, and presents numerous solitary outcrops in river banks and colluvial plains where it is conspicuously green with up to 40% glauconite. Mineralogical and chemical sampling has focused on the LGS in EL30603.

A collection of 10 grab samples from the bank of the Daly River have been subject to a combination of XRD analysis, crushing screening with magnetic separation, and XRF analysis of both whole-rock and glauconite concentrates. The sandstones contain rounded glauconite grains 0.2–0.8mm in diameter, and sub-angular detrital quartz grains 0.1–0.4mm in diameter, as the major components. The absence of carbonates and potash feldspar indicated K<sub>2</sub>O and Fe<sub>2</sub>O<sub>3</sub> can be used to estimate modal content of glauconite, which in this collection averages 37%. Trial magnetic separation on four crush sizes (+500, 280-500, 106-280, and <106 µm) at various magnetic settings showed a clean concentrate can be achieved with grind size 106 - 280µm with magnetic field setting of 9400 Gauss.

SEM EDS analysis showed that most glauconite grains contain abundant inclusions of apatite (phosphorite) at the micron scale. Initial estimate of the chemical composition of the glauconite concentrate is 7.45% K<sub>2</sub>O and 2.65% P<sub>2</sub>O<sub>5</sub>.

Preliminary kinetic leach tests on glauconite concentrate using sulphuric acid and citric acid were done by the CSIRO. Ring-grinded P80 25µm concentrate achieved a high 40% potassium extraction after eight hours with hot citric acid, comparable to that for hot sulphuric acid. This enhanced dissolution with ring-grinding may be due to mechanical activation.

A larger composite sample of sandstone of about 37% glauconite content was crushed to P80 106µm and deslimed at 38µm. It yielded 12kg of high-quality concentrate. This was thermally activated and subject to both standard fertilizer analyses at ambient temperature and kinetic leach tests at elevated temperature.

NAC (neutral ammonium citrate) analyses showed a twelve-fold increase in potassium release from activated glauconite relative to non-activated glauconite. Similarly CA (5% citric acid) analysis indicated full release of potassium may be achieved over an annual plant growing cycle.

Follow-up kinetic leach tests were conducted on activated glauconite over an extended period of 48 hours at 95<sup>0</sup>C, on size fractions of 48µm-106µm, and P80 38µm. Both size fractions showed near-100% dissolution of both potassium and phosphorus over periods of 48-60 hours.

Leach results demonstrate Florina glauconite may deliver either a slow-release potassium fertiliser with phosphate credits, or feedstock for industrial potash with phosphate and sulphates as by-product. Further kinetic leach tests will be required to optimize the extraction of potassium in terms of temperature, acid strength, leach time, grind-size, and catalysts. Such tests would define the preferred product path. Drilling is now required to define a resource, and provide material for further metallurgical and chemical tests.

## Introduction

The Florina Potassium-Phosphate Project is based on extensive Ordovician sandstone sequences containing the mineral glauconite – a potential source of potassium fertiliser with phosphate credits, suitable for local and national agricultural use.

Glauconite is a potassium-rich mica mineral containing up to 9% K<sub>2</sub>O. It is paramagnetic which enables it to be beneficiated by magnetic separation to form a bright green granular concentrate. Raw glauconite is marketed in the United States as agricultural greensand where it has been extensively promoted as a slow-release potash fertilizer, although this claim is doubtful. Glauconite can also be a feed for potash production.

Glauconite has long been considered a potential source of potash since the historic Tshirner process of 1918 involving high-temperature roasting with calcium carbonate and common salt (Sharma 1997). Subsequent attempts over the century have pursued the pyrometallurgy approach (Verde Potash 2013), and combination pyrometallurgy-hydrometallurgy involving sequential roasting and leachings with hot mineral acids (Potash West 2013). All these subsequent processes are disadvantaged by high energy demand, and high capital and operating costs. Tracker's Florina Project is pursuing an innovative process of leaching specially activated glauconite with benign organic acid.

Potash refers to any salt of potassium, which can be in the form of chloride, sulphate, nitrate or carbonate. Potash is an essential component of NPK fertiliser, however all forms of potash are highly soluble and readily leach from soils. Australia has no geological resources of the conventional rock-salt type of potash. Consequently all requirements are imported, generally in the form of bulk shipments of potassium chloride (MOP) and potassium sulphate (SOP). Whereas the global price of MOP is currently depressed, the much preferred SOP product sustains high prices. Demand for non-chloride potash is steadily growing to meet increasing horticultural and farm use, particularly in tropical Australia.

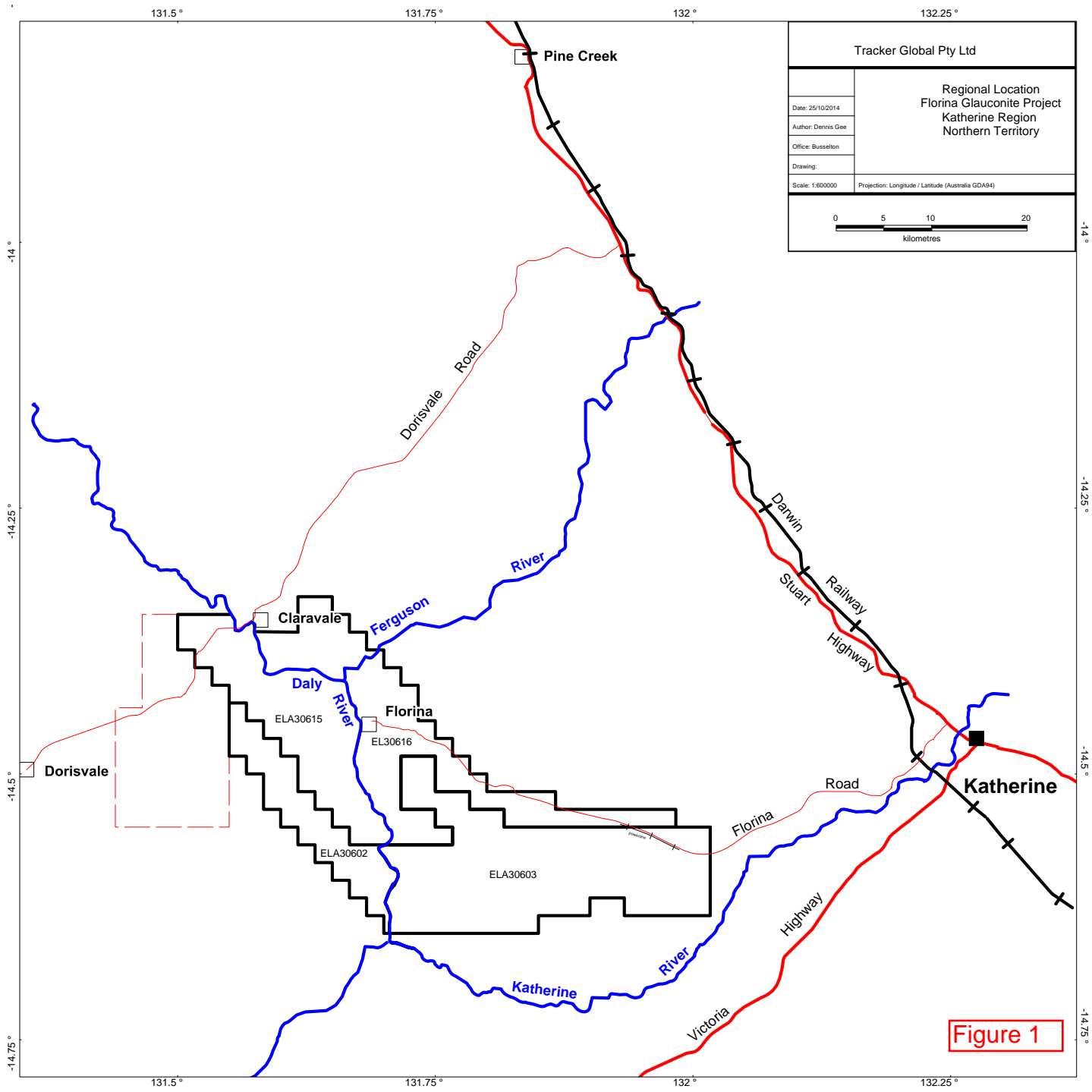
Tracker Geoservices reviewed the occurrences of glauconite in the top end of the Northern Territory. A glauconite layer has long been recognized at the base of the Cretaceous sequence around Darwin. This was mapped using surface exposures and water-bore cuttings, where it is expressed as a honey-comb textured ferricrete. However in every instance it is heavily lateritized and totally leached of potassium. Attention then turned to Ordovician glauconitic sandstone in the Daly Basin.

Exploration commenced in October 2014 within the 12 month period prior to grant of the exploration licenses. Consequently this initial information is reported here and claimed as project expenditure. The early exploration strategy at Florina has been to focus initially on the downstream processing concepts, rather than first defining a resource. This is quite the reverse of a conventional mineral exploration strategy, but it is an appropriate strategy required by the nature of this project.

## Project Location and Access

The project is centred on Florina Pastoral Station 70 km west of the regional town of Katherine in the Northern Territory. Access is via Florina Road which is sealed for the first 32 km, and then 38km along unsealed all-weather graded road to Florina Station Homestead.

Katherine is a regional centre servicing well-developed horticulture, agriculture and cattle ranching, all of which rely on the Daly River Groundwater Region. Katherine is serviced by the Stuart Highway and the Adelaide-Darwin Railway (**Figure 1**). The Amadeus Basin-Darwin gas pipeline passes along the railway easement, and provides electricity generation to the region. A 27KV powerline extends



131.5°

131.75°

132°

132.25°

-14°

-14.25°

-14.5°

-14.75°

-14°

-14.25°

-14.5°

-14.75°

Pine Creek

Dorisvale Road

River

Ferguson

Daly River

Claravale

ELA30615

Florina

EL30616

ELA30602

ELA30603

Katherine

Victoria Highway

Highway

Florina Road

Katherine

Darwin

Stuart

Railway

Highway

along Florina Road and cuts across the northeastern corner of the project area and terminates 28km short of Florina Homestead.

## Tenure

Tracker Global Pty Ltd has two granted ELs southeast and north of Florina Homestead.

EL	Name	Location	Blocks	Grant Date
30603	Mullens	Yujallowan Creek, southeast of Florina Homestead	109	30 Jul 2015
30616	Fergusson	Lower Fergusson River, north of Florina Homestead	85	30 Jul 2015

They are subject to group reporting under GR427, and approved project-expenditure-area reporting. Both technical and expenditure reports are due on 30 September.

## Regional Geological Setting

The Daly Basin is a sequence of mostly Middle Cambrian sedimentary rocks that occupies a broad gentle synclinal downwarp between the basement highs of the Pine Creek Orogen to the northeast, and the Birrindudu-Victoria province to the southwest. As such it also occupies a topographically low region of the Daly River catchment. It is characterized by extensive cover of Cretaceous sandstone and colluvial-alluvial sands. Consequently rock outcrops are sparse.

The western margin of the basin is characterized by a group of northwest-trending normal faults that may in part, be growth faults related to basin formation. The most conspicuous of these is the Dorisvale Fault that separates the Tyndall Limestone - Jindukin interval of the Daly River Group from the basement to the west. These fractures coincide with uranium and REE anomalies (see later section). A thin basalt layer of the Kalkarindjie Suite (Antrim Basalt) also occurs at the western margin of the basin,

The Middle Cambrian sequence (known as the Daly River Group), consists of the Tindall Limestone, overlain by the Jinduckin Formation (dolomitic siltstone), and capped by the Ooloo Dolomite. These units are compressed facies variants of the widespread and much thicker Middle Cambrian sequences of the contiguous Wiso and Georgina Basins well to the south.

## Previous Exploration

In the period 1967-1968, the general area of the Daly Basin was subject to phosphate exploration, as part of the greater phosphate search in the central Georgina Basin. This resulted in the discovery of the large phosphorite deposits in the Middle Cambrian Wonarah Formation, of which the actual Wonarah deposit of 1,258Mt at 12% P<sub>2</sub>O<sub>5</sub> is the largest deposit, albeit still undeveloped. The Wonarah Formation is temporally equivalent to the pre-Florina Daly River Group, but this phosphatic siltstone is not present in the Daly Basin.

In 1967 IMC Development (CR1967-0020) conducted a phosphate search in the general Daly River Basin on old AP1682. This included geological observations on the Bowman 100k sheet (5268), on which the Florina Project is located.

In 1968 Continental Oil Co (CR1968-0017) also undertook a phosphate search on old AP1693. The highest P<sub>2</sub>O<sub>5</sub> values were around 2% in siltstone-limestone of the upper Tindall. It concluded “although observed features in the limestone appeared encouraging with respect to phosphate deposits the necessary facies change towards phosphogenic sediments was not found and is unlikely”.

Since then no geological exploration has been conducted in the area for phosphate-potash minerals, or indeed any other minerals, except for diamond exploration by BHP and Stockdale Prospecting in the period 1988 – 1991. The NTGS MODAT mineral database does not record any mineral occurrences within, or in the immediate vicinity of the Florina Formation.

Spectrum Rare Earths Ltd (ASX:SPX) recently explored the area to the west of the Tracker Florina ELs for rare earths and uranium. SPX claims a “midpoint” Exploration Target of 19Mt at 0.5% HREE at Skyfall which was their premier prospect. Enriched values of heavy REE (mostly yttrium and dysprosium) occur in an elongate surface anomaly 9km long, coinciding with a cluster of faults related to the Dorisvale Fault. The anomalous rare-earth elements are in secondary weathering minerals (florencite and crandallite) after the primary mineral xenotime, which is a rare-earth phosphate. The REE minerals occur as a near-surface seemingly stratiform layer within weathered ferruginous sandstone. This unit is underlain by dolomite (probably Tindall Dolomite), which is underlain by Kalkarindji Basalt.

Other lines of fault-related REE anomalism occur further to east within the Jinduckin Dolomitic Siltstone, defining the undrilled Largo and Knightfall prospects. SPX’s eastern-most tenement ELA 29240 captures a topographic lineament in the Ooloo Dolostone. It encroaches onto the Florina Formation, on the western side of Daly River. Tracker’s ELA Bowman abuts SPX’s ELA29240. No surface REE anomalism has been reported by SPX in this area. The origin of these curious deposits is unclear, however they are fracture-related and occur in a variety of host rocks, including pre-Daly River Group. No igneous activity affects the Daly River Group.

## Geology of the Project Area

### Florina Formation

The Florina Formation has only recently been recognized as a separate stratigraphic entity, based on fossil dating which puts it into the Lower Ordovician, significantly younger than the Daly River Group (Kruse et al 2012). It occurs over an area 72km long and 17km wide in the axial part of the Daly Basin (**Figure 2**). It is 167m thick as defined in stratigraphic bore RN37043, which penetrated the entire formation (Tickell 2008).

Water bore RN37043 was drilled by NTDNRE in June 2010 to evaluate aquifers within and around the Florina Formation. It was collared in Cretaceous, penetrated the full extent (153m) of the Florina Formation, and finished in Ooloo Limestone at a total depth of 230m. As such it is the definitive stratigraphic reference section for the Florina Formation. It was drilled by open-hole rotary percussion with roller and hammer bits, variably using air and foam, with several strings of progressively narrower casing in order to preserve the integrity of the hole. A reasonable return of drill cuttings with minimal contamination can therefore be expected.

The lithological intervals have been identified principally by geological logging by S Tickell of NTDNRE, and the formation tops have been precisely defined by down-hole gamma logging. Major stratigraphic units are summarized in the following table.

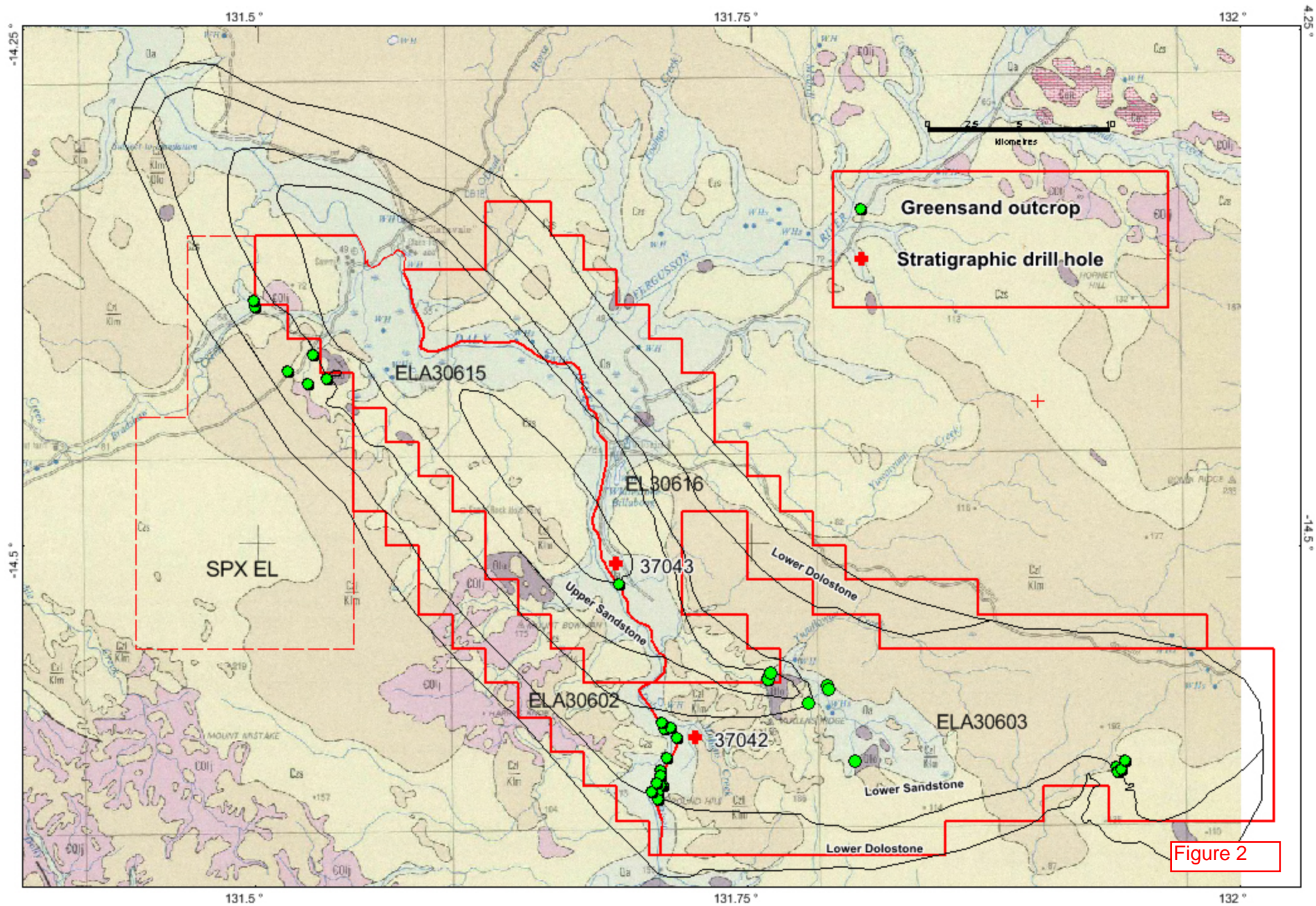


Figure 2

From	To	Interval	Lithology Stratigraphy	Comment
0	25	25	Cretaceous	
25	39	14	clay, uncertain if Cretaceous or Florina	may be some weathered upper Florina limestone
39	79	40	Upper Sandstone 5-10% glauconite	only one known outcrop in Daly River
79	84.5	5.5	Shale	Included in Upper Sandstone
84.5	104.5	20	Middle Limestone	no shale recorded
104.5	162	57.5	Lower Sandstone	current prime target, fine ssn and shale toward top
160.5	192	31.5	Lower Limestone	interface of Lower Limestone and Ooloo is karstic
192	230	38	Ooloo Limestone	

Stratigraphic units of Florina Formation

Another stratigraphic hole, RN37042 was collared in the lower sandstone and recorded 67m of glauconitic sandstone (LGS), before intersecting the underlying Ooloo Dolomite.

**Figure 2** shows an interpretation of the distribution of the individual members of the Florina Formation by Tickell (2010) but modified following further geological mapping in October 2015. In this figure the extensive cover of Cretaceous has been removed to give clarity to the overall picture. Also shown on Figure 2 are the locations of the two stratigraphic holes, and some of the main exposures of glauconitic sandstone. Exposures occur in river banks, creek beds, road cuttings and rare cliff outcrops.

## Lower Glauconitic Sandstone (LGS)

This member conformably overlies the Lower Limestone and is well exposed in the Daly River. Many isolated outcrops occur in the catchment of the Yujullowan Creek, mostly in stream beds and isolated exposures.

The sandstone is well sorted and fine grained with lesser medium and coarse-grained beds. Bedding units range up to 0.5 meters in thickness. Thinner beds have a flaggy appearance and contain millimetre-scale shale partings. Shale laminae commonly show feeding trails on bedding planes. Beds are generally continuous over the scale of an outcrop, but lenticular beds do occur. Trough cross-bedding is seen in thicker beds. Fine shell fragments are present and fresher rocks are weakly calcareous. Wave and current ripples are seen in most outcrops.

Glauconite occurs throughout the LGS member, varying up to 40% in volume. It is present as fine to medium-grained rounded pellets. Its content varies considerably from bed to bed and also within an individual bed. Thicker beds of medium-grained sandstone tend to have higher concentrations. The upper third of the LGS member appears to be richer in glauconite with contents between 20 - 40%. The lower section on average contains less than 10% glauconite. This seems to be the case in both the Daly River exposures and in the Yujullowan Creek exposures.

The Daly River has incised 20m into the sandstone, exposing fresh rock. Exposures in the Yujullowan catchment are slightly weathered to a khaki-brown colour, and the glauconite grains are partially oxidized to iron oxides. Fresh green rock was observed at a couple of localities in the Yujullowan catchment.

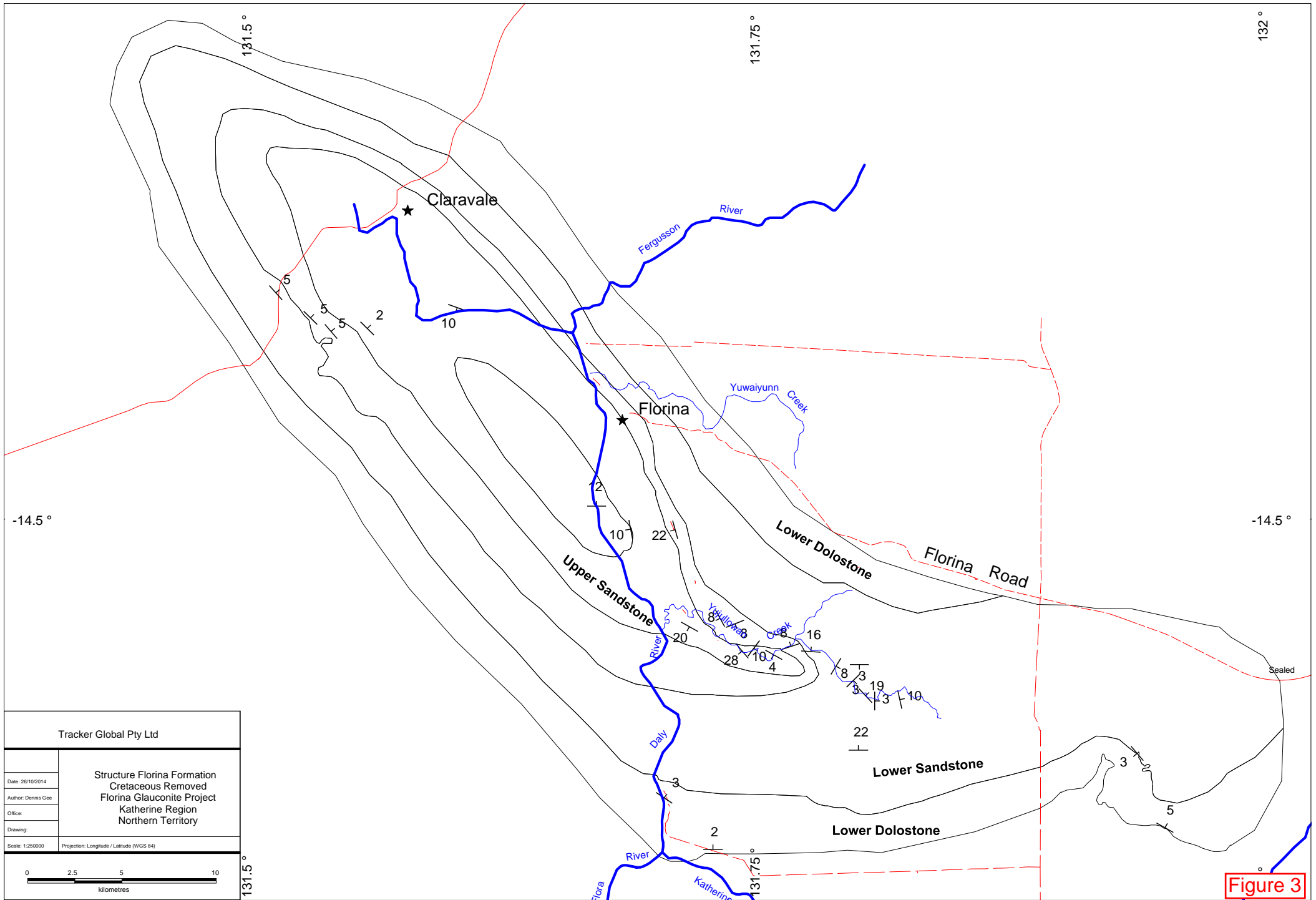


Figure 3

## Upper Glauconitic Sandstone (UGS)

This member was initially identified from drill holes and a solitary outcrop in the Daly River. Recent mapping had identified six new exposures along Yujullowan Creek. It is a fine-grained sandstone similar to the LGS. Lithology and sedimentary structures are virtually identical. Glauconite contents range from 5 to 40%.

## Structure of the Florina Formation

**Figure 3** shows the broad synclinal nature of the Florina Formation, with the extensive Cretaceous strata removed for clarity. Generally beds dip basinwards at such low angles that strikes and dips cannot be measured precisely in the field. The dip angles shown in **Figure 3** are probably atypical of the overall structure. However there is considerable local variation in strike and dip in the form of gentle wavy deformation, which may be related to faults. One particular zone of disturbance occurs around the southern closure of the UGS 15km southeast of Florina Homestead. Here dips of  $10^{\circ}$  –  $20^{\circ}$  are present with abnormal strike azimuths that do not conform to the gentle syncline. This is probably a fault zone, and such disturbance should not negate simple open-pit quarry operations in the event of a mining development.

Such faults may be post-Cretaceous as there are also localized zones of contorting, fracturing and slickensiding in the otherwise flat dipping Cretaceous strata.

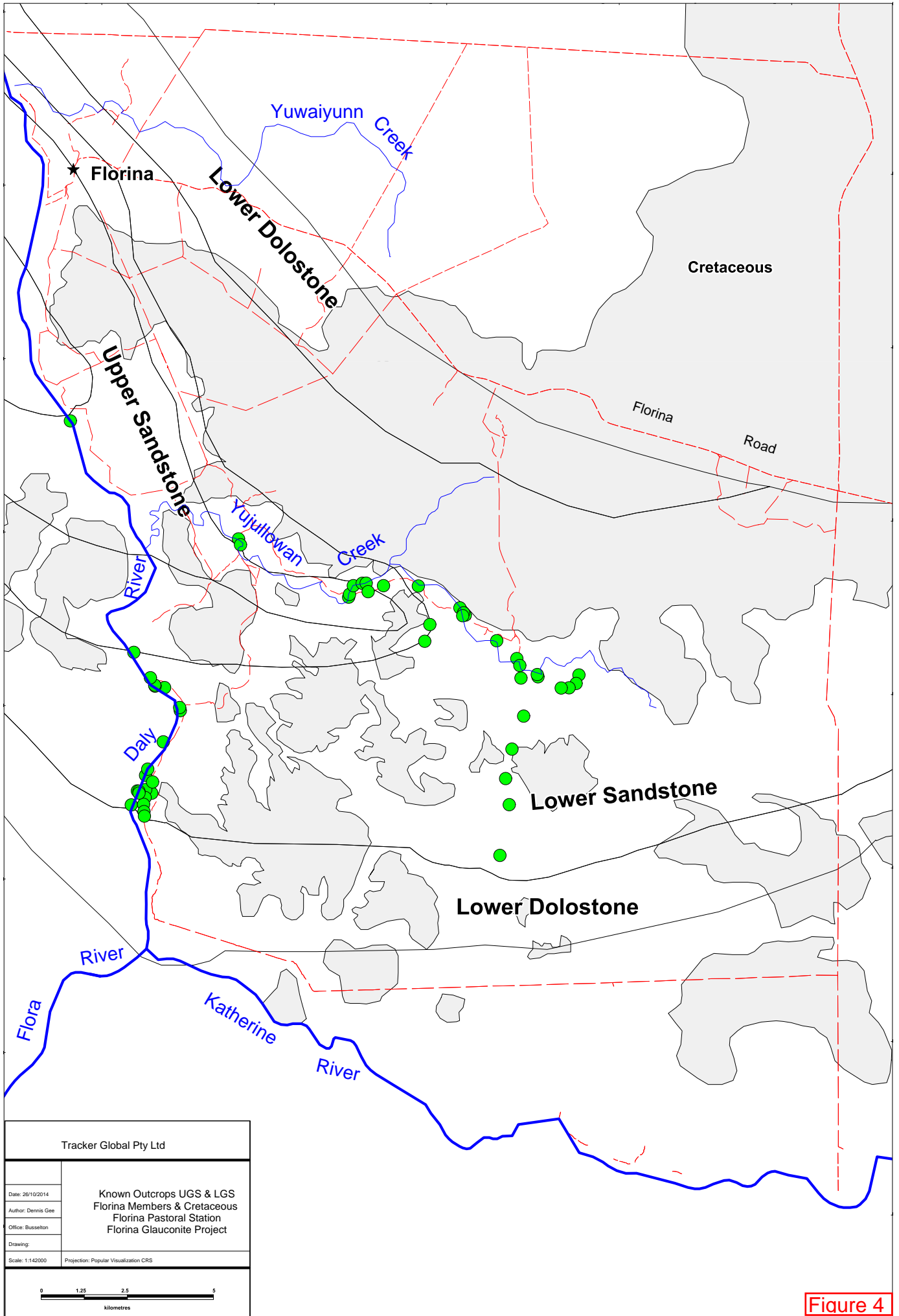
## Distribution of Cretaceous

An important factor in identifying prospective areas is the distribution of Cretaceous cover in relation to the prospective LGS and UGS members.

The main areas of Cretaceous are mostly expressed as flat elevated mesa-type landforms with scarps 20-30m in height, and invariably capped by lateritic duricrust. The Cretaceous landforms represent the remnants of a once-continuous transgressive sequence of fluvial and shallow-marine sandstones. Lateritic weathering has not affected the underlying Florina Formation.

**Figure 4** shows an extensive cover of Cretaceous on the plateau land in the central part of the Florina pastoral lease, along which the main Florina Station access road runs. Waterbore drilling indicates this has an average thickness of 34m meters, but can reach up to 65m depth in possible depocenters. Such thicknesses present prohibitive overburden for prospective mining.

South of the main scarp there are numerous outliers of Cretaceous on the gentle slopes of the Katherine River valley. Although some of these small residual hills of Cretaceous may have thickness of 30 m, many of the outliers represented on **Figure 4** are thin skins of the basal Cretaceous sandstone. In effect there is a large tract of underlying LGS that would not be constrained by excessive overburden.



**Figure 4**

## Outcrops of Glauconitic Sandstone

Known outcrops of glauconitic sandstone are plotted on **Figure 4**. Best exposures occur in the river bank of the Daly River, at the Boat Landing Locality (792112mE/8385039mN) and the Point Bar Locality (791480mE/8385572mN). These are fresh, un-oxidised green sandstones, partially leached of their carbonate cement, such that they are friable. They represent the Lower Glauconite Unit.

A string of solitary outcrops occur in the middle and upper reaches of Yujullawon Creek, protruding through thin cover of colluvium and alluvium. These are variously oxidized and in places quite indurated. These represent both the Lower Glauconite Unit and the Upper Glauconite Unit.

## Mineralogical Testing of Glauconite Sandstone

### Rock chip Samples

A collection of 10 samples, tabulated below, have been subject to mineralogical analysis by Townend Mineralogy, using a combination of XRD analysis, crushing screening with magnetic separation, and XRF analysis of both whole-rocks and glauconite concentrates.

Sample	Location	Description
GNT014	Daly river Point Bar locality	Sandstone, 40% glauc, friable leached, green, donated by ST
GNT015	Daly River Boat Landing	Sandstone, glauc 40%, green, concentrated on x-bedded laminae
GNT016	Daly River Pt Bar Locality	Sandstone, glauc 20%, green, concentrated on x-bedded laminae
GNT017	Yujullowan Creek crossing	Sandstone, glauc 30%, green concentrated on x-bedded laminae
GNT018	Yujullowan Creek crossing	Sandstone, 30%glauc, cemented, pink-green claystone clasts
GNT032	left bank Yujullowan Creek	Sandstone, glauc 10%, coarse grained, green-brown, acid reaction
GNT033	left bank Yujullowan Creek	Sandstone, glauc 5%, green, fine grained, cemented, fossil trails
GNT035	headwaters Yujullowan Creek	Sandstone and shale, glauc 10%, pale brown, fine grained,
GNT036	headwaters Yujullowan Creek	Sandstone, glauc 20%, pink-brown, medium grained
GNT038	headwaters Yujullowan Creek	Sandstone, glauc 20%, pink-brown, medium grained, cemented

**Description of initial ten-sample collection of LGU**

The samples were selected from outcrops to cover a range of glauconite contents, grain-sizes and oxidation states. Most are on EL30603, and GNT017, 018, 032, 033 are on EL 30616.

Parameters for testing were set after initial testing of Sample GNT014. Details of the tests are given in Townend Reports 23728 (initial sample), and 23757 Parts (1) and (2) dealing with nine subsequent samples. Results are summarized in this section.

### Petrography

No specific thin-section petrography has been undertaken, but generic descriptions are summarized from the mineralogical work. The sandstones contain rounded glauconite grains 0.2–0.8mm in diameter, and sub-angular detrital quartz grains 0.1–0.4mm in diameter, as the major components. The remainder is single grains of calcite, apatite and potash feldspar, and interstitial cement of as yet undetermined composition. There is no mosaic texture or suturing between individual quartz grains, and only a small amount of pressure solution of glauconite into quartz grains is evident. This indicates minimal compaction, and individual grains should be effectively separated during grinding.

When fresh the glauconite grains are bright green, imparting to the rock a green-and-white peppered appearance. When slightly oxidized the glauconite grains are light brown, giving the rock a salmon pink to light brown colour.

## XRD analysis

Whole-rock fractions were analysed by x-ray diffraction (XRD) to identify all mineral phases. This revealed the presence of apatite both as cryptocrystalline material within the glauconite, and as small (0.2mm dia) single-crystals of apatite among the quartz grains. It is not clear from XRD or thin sections whether the single-crystal apatite is authigenic or detrital.

Glauconite (mica) and quartz were shown to be major (>20%) components in all samples except GNT035 where glauconite was a minor component (<20%), and potash feldspar was a major component. GNT033 recorded 10-20% potash feldspar with major (>20%) dolomite. Potash feldspar (which will contribute K<sub>2</sub>O to the whole rock geochemistry) was confirmed by staining.

Because of its part amorphous crystal structure, the amount of glauconite is difficult to quantify by XRD. Glauconite content in the whole rock is discussed in a later section.

## Head analysis

Whole-rock portions of the ten samples were submitted for chemical analysis of major element oxides. Significant results are tabulated below.

Sample	Al <sub>2</sub> O <sub>3</sub>	CaO	Fe <sub>2</sub> O <sub>3</sub>	K <sub>2</sub> O	MgO	P <sub>2</sub> O <sub>5</sub>	SiO <sub>2</sub>	LOI
GNT014	4.68	4.13	10.70	4.38	1.93	2.89	67.95	2.84
GNT015	4.39	2.04	8.69	3.69	1.02	1.41	77.42	1.02
GNT016	3.33	2.21	4.58	2.59	0.68	1.59	83.01	1.00
GNT017	2.19	10.13	7.45	2.00	4.82	1.12	59.83	11.87
GNT018	4.47	2.42	6.14	3.19	0.91	1.79	78.68	1.51
GNT032	1.79	7.50	1.06	1.72	4.52	1.06	65.62	9.64
GNT033	4.84	12.13	4.90	3.31	8.07	0.52	47.97	17.98
GNT035	9.18	0.06	3.88	5.78	0.68	0.08	78.46	1.50
GNT036	3.03	2.78	9.13	2.34	2.24	0.43	75.88	4.21
GNT038	4.76	0.05	6.20	3.34	0.88	0.89	81.88	1.53

Major element analysis of initial ten-sample collection of LGS

According to the mineral components identified by XRD, all the Fe<sub>2</sub>O<sub>3</sub> occurs in glauconite and in this case can be used to calculate modal content of glauconite in the whole rock (see later section). K<sub>2</sub>O values can also be used in this respect providing potash feldspar is absent, even though it is a minor or accessory mineral component. Similarly all the P<sub>2</sub>O<sub>5</sub> reports in apatite. Townend Mineralogy notes that there is more CaO than is accommodated in apatite, so the excess CaO reports into calcite cement.

The LOI (loss on ignition) results from the loss of molecular water in glauconite, and decomposition of calcite during ignition.

Other elements analysed (Na<sub>2</sub>O, Cr<sub>2</sub>O<sub>3</sub>, TiO<sub>2</sub>, MnO and S) were negligible, and not tabulated above.

## Magnetic separation

The initial sample (GNT014) was subject to magnetic separation of six different crush sizes to determine optimum yield for a glauconite concentrate. This rock was lightly crushed and screened to +500, +400, +300, +212, +107 and -107 $\mu$ m. Each fraction passed through a dual-disc rapid magnetic separator with three magnetic settings - highly magnetic (M1), weakly magnetic (M2) and non-magnetic (M3). Being weakly magnetic, glauconite preferentially reports into the middle fraction. For the initial sample, the highly magnetic fraction (mostly glauconite) amounted to 4.7% by weight, the M2 fraction (entirely glauconite) amounted to 55.9%, and the non-magnetic M3 fraction was 39.4% of the feed.

The nine subsequent samples were crushed and screened to four size fractions (+500, 280-500, 106-280, and <106  $\mu$ m), and five magnetic settings - highly magnetic (M1), moderately magnetic (M2-M3) weakly magnetic (M4) and non-magnetic (M5). Virtually all the glauconite came out in the M4 fraction which corresponds to a 9400 Gauss field. This showed a clean concentrate can be achieved with grind size between 106 and 280 $\mu$ m. Within this range there is good liberation of glauconite with only minimal adhesions of other material. Above 280 $\mu$ m there is significant compositing of grains, and below 106 $\mu$ m there is a clean fine fraction of glauconite. The Mag1-3 fractions produced negligible weights, indicating absence of ilmenite and magnetite.

## Chemical analysis of glauconite concentrate

Chemical analysis by XRF of various size fractions of the glauconite concentrate are tabulated below.

Sample	Size $\mu$ m	Al <sub>2</sub> O <sub>3</sub>	CaO	Fe <sub>2</sub> O <sub>3</sub>	K <sub>2</sub> O	MgO	P <sub>2</sub> O <sub>5</sub>	SiO <sub>2</sub>	LOI	Others
GNT014	106-212	8.50	4.53	18.78	7.19	3.52	3.05	47.92	5.10	1.41
GNT014	212-300	7.05	4.14	19.50	7.15	3.48	2.79	50.54	4.83	0.52
GNT015	106-280	7.66	3.07	21.30	7.57	3.70	1.95	49.45	5.00	0.30
GNT015	280-500	7.17	3.23	21.34	7.49	3.71	2.07	49.82	4.96	0.21
GNT016	106-280	8.39	3.69	19.58	7.51	3.77	2.47	49.43	4.92	0.24
GNT017	106-280	6.13	6.19	20.99	7.41	3.94	3.16	46.12	6.01	0.05
GNT017	280-500	5.59	6.73	20.50	7.23	3.99	3.10	46.13	6.50	0.23
GNT018	106-280	8.41	3.41	19.88	7.58	3.68	2.40	49.18	4.89	0.57
GNT032	106-280	6.68	4.83	20.76	7.42	4.16	2.88	47.54	5.54	0.19
GNT032	280-500	6.53	4.30	21.18	7.47	3.99	2.68	48.06	5.24	0.55
GNT036	106-280	7.75	0.18	24.89	7.67	3.71	0.10	50.07	5.33	0.30
GNT038	106-280	8.67	0.19	21.29	8.27	3.98	0.19	52.13	5.03	0.25
<b>Average</b>				<b>20.83</b>	<b>7.50</b>					

Major element analysis of concentrates from the initial ten-sample collection

The following points are relevant:

- High-purity glauconite concentrate is recovered from every sample, with remarkable consistency of K<sub>2</sub>O that averages 7.5%.
- There is no chemical difference between the different size fractions of the same sample
- There is no chemical difference between the green and brown glauconites indicating there is no loss of potassium with surface weathering
- Fe<sub>2</sub>O<sub>3</sub> averages 20.8%, close to the stoichiometric value (24.3%) of ideal glauconite.
- The values of CaO and P<sub>2</sub>O<sub>5</sub> are consistent with the presence of apatite in the glauconite, with only little carbonate.
- Samples GNT036 and 038 have virtually no CaO and P<sub>2</sub>O<sub>5</sub>, and are devoid of apatite
- The average P<sub>2</sub>O<sub>5</sub> (excluding GNT036 and 038) is 2.65%
- LOI (loss on ignition) is entirely due to molecular OH in the glauconite.
- "Others" include minimal amounts of Cr<sub>2</sub>O<sub>3</sub>, MnO, Na<sub>2</sub>O, SO<sub>3</sub> and TiO<sub>2</sub>

Samples GNT033 and 035 gave minimal recovery in the magnetic separation because of fine grain size, and results are not included in this table.

The average of the six samples (bold in previous table) with significant phosphorite (apatite) inclusions is given in the table below. This is the initial estimate of the chemical composition of a glauconite concentrate.

Concentrate Analysis	Al <sub>2</sub> O <sub>3</sub>	CaO	Fe <sub>2</sub> O <sub>3</sub>	K <sub>2</sub> O	MgO	P <sub>2</sub> O <sub>5</sub>	SiO <sub>2</sub>	H <sub>2</sub> O	Totals
	7.63	4.29	20.22	7.45	3.80	2.65	48.27	5.24	99.54

## SEM EDS analysis

Various fractions of concentrate were analysed by scanning electron microscope – energy dispersive system, which give images and semi-quantitative chemical analysis at the micron scale. This showed that all the glauconite grains from all but two samples contain abundant inclusions of apatite (phosphorite). Apatite patches within the glauconite grains are identified by bright back-scatter patches in the SEM image (see **Figure 5**). Patches of pure glauconite contain 8-9% K<sub>2</sub>O with no phosphate, whereas patches of apatite within the glauconite grain contain 33-40% P<sub>2</sub>O<sub>5</sub> and 45-57% CaO, with minimal K<sub>2</sub>O.

Apatite inclusions take the form of irregular blotches and sinuous wisps on a scale of 5µm to 50µm scattered irregularly throughout the glauconite grains, within no evidence of crystal control or concentric growth. SEM images indicate apatite may occupy as much as 50% of the glauconite grains, but nothing approaching full replacement has been observed. Moreover there is nothing resembling discrete nodules of phosphorite.

This fine-scale co-mingling would point to poor liberation of apatite and glauconite even at fine grinding down to 10 µm or less. Consequently the glauconite and apatite would need to be processed chemically together to liberate their respective potash and phosphate.

The two samples devoid of apatite inclusions (GNT036 and 038) come from the upper reaches of Yujullowan Creek which are in the Lower Glauconite Sandstone. These samples, along with Sample GNT035 (not subject to SEM-ED analysis) also have low P<sub>2</sub>O<sub>5</sub> in the whole-rock XRF analyses.

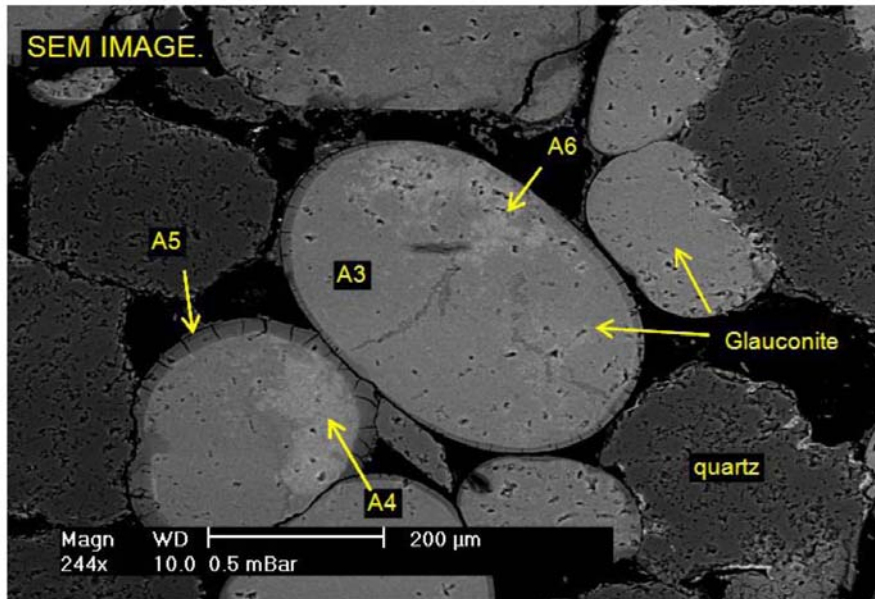
## Trace elements in glauconite

Eight samples of glauconite concentrate were submitted to Intertek for analysis of the suite of standard trace elements relevant to fertilizers (tabulated below).

Elements	B	Cd	Cl	Co	Cu	F	Hg	Mo	Pb	Se	Zn
Units	ppm	ppm	%	ppm	ppm	ppm	ppb	ppm	ppm	ppm	ppm
Detection	50	0.02	0.02	0.1	0.5	50	1	0.1	0.5	0.5	1
GNT014	58	0.04	X	17.7	16.9	4001	7	0.2	7.3	X	40
GNT015	X	X	X	24.2	4.7	2903	3	X	10.9	X	41
GNT016	X	0.03	X	19.1	8.6	3409	20	X	5.5	X	42
GNT017	X	0.02	X	21.3	5.3	3849	11	X	3.7	X	30
GNT018	X	X	X	24.8	6.4	4170	4	X	3.4	X	56
GNT032	X	X	0.03	21.8	5.8	3700	9	X	8.2	X	33
GNT036	X	0.03	X	47.3	33.6	2021	7	X	4.4	X	180
GNT038	X	0.02	X	32.9	8.4	2021	9	X	43.4	X	92

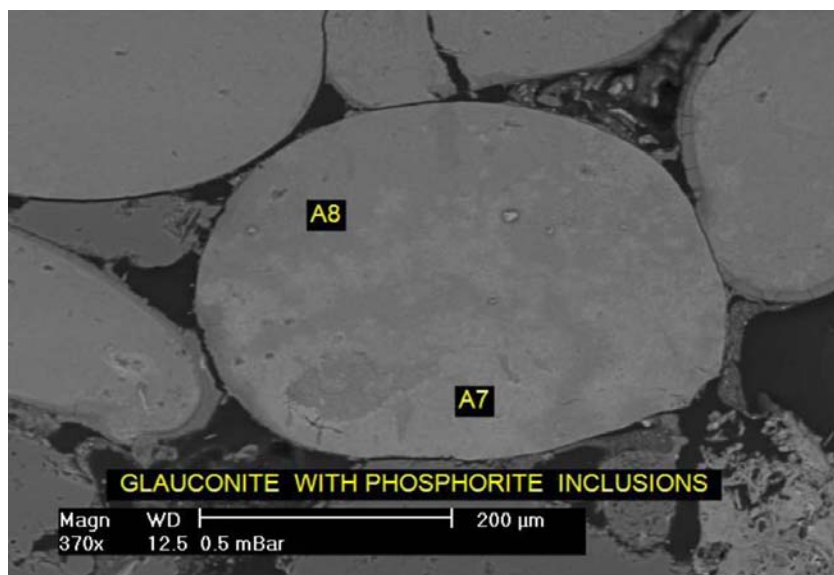
Note: X represents below detection limit

Trace element analyses of initial ten-sample collection



**SEM/EDS ANALYSES**

Wt%	1	2	A3	A4	A5	A6	A7	A8
MgO	5	4.5	4.5	1	4	1	1.7	5.0
Al <sub>2</sub> O <sub>3</sub>	9.7	8.1	8.2	4	13.7	1	3.3	9
SiO <sub>2</sub>	62.5	59.8	59.5	20.5	67	13.5	15.5	61
K <sub>2</sub> O	7.9	8.8	8.7	2.5	4	2.0	1.8	8
FeO	14.7	18.8	19.0	3.6	7	3	2,9	16
P <sub>2</sub> O <sub>5</sub>				33.1		34	35.5	0.7
CaO				34.9		43	39.7	0.6



**Figure 5.** Scanning Electron Microscope (SEM) images and analyses of glauconite grains with included phosphorite (pale off-white) patches

It is evident that Florina glauconite is very low in trace elements that could be considered beneficial or deleterious. The exception is the high fluorine (indicating presence of fluor-apatite) which is normal for phosphorite, and is not considered deleterious.

## Non-magnetic sinks

For the initial sample GNT014, the non-magnetic fraction was further separated using tetra-bromine ethane (TBE) which is a heavy liquid with specific gravity of 2.97.

About 15% of the non-magnetic fraction formed a TBE sink, most of which is apatite. This occurs as both combined glauconite-phosphorite grains in the plus 212  $\mu\text{m}$  size fraction, and predominantly discrete apatite grains in the finer minus 107 $\mu\text{m}$  fraction. This suggested that some glauconite may be escaping capture during the magnetic separation and reporting with the mostly non-commercial quartz gangue. Chemical analyses of the non-magnetic sinks were not made.

Subsequently, during the preparation of a min-bulk sample of concentrate from a range of several grab samples, the non-magnetic fraction yielded only 0.5% to 1.5% TBE sinks (Townend Report 23807, Mar 2015), contrary to the initial sample GNT014. These are very low values and indicate some variability of single-grain apatite within the glauconitic sandstone. This aspect needs to be re-examined when proper quantitative mineralogy is done on drill core.

## Glauconite content and yield

A metallurgical method for establishing the glauconite content of the whole rock has not yet been established. This is important in establishing the yield from magnetic separation.

Glauconite content may be estimated from the summation of the percentage magnetic recoveries from each individual size fractions, as tabulated in the following table. This gives minimum values as it takes no account of composites in the M4 magnetic fraction and loss of fine glauconite to the non-magnetic fraction.

Sample	Visual Estimate %	Magnetic separation	Modal from Fe	Yield%
GNT014	40	44	51	86
GNT015	30	20	36	56
GNT016		10	19	55
GNT017	30	9	31	28
GNT018	30	13	25	51
GNT032	10	10	36	28
GNT033	5	not done	20	
GNT035	10	not done	16	
GNT036	20	19	38	50
GNT038	20	11	26	42

Inferred glauconite modal content and yield of initial ten-sample collection

A better way of estimating glauconite content is to assume all the iron ( $\text{Fe}_2\text{O}_3$ ) is in glauconite - a valid assumption. The average of the ten Florina glauconite concentrates is 20.8%  $\text{Fe}_2\text{O}_3$ . The modal glauconite content is the ratio of  $\text{Fe}_2\text{O}_3$  in whole rock and in concentrate, as shown in the above table.

The ratio of the magnetic separation against the “modal” content gives the yield. The yield figure is variable and obviously needs to be tested by proper metallurgical testing, which these initial mineralogical tests do not purport to be. It is proposed that a yield of 70% be used in initial concept studies.

## **Leach Testing of Glauconite**

### **CSIRO Preliminary Solubility Test**

Preliminary leach tests using concentrated sulphuric acid and citric acid were done by CSIRO in 2015, on left-over material derived from the Townend magnetic concentrate on the 10-sample composite. Two grind-size products were used - ball milled, and ring-ground 25µm material. Slurries of 10% w/w of each milled product were subject to 10-hour agitated leach tests in concentrated (4M) citric acid, and 2.5M sulphuric acid, at sub-boiling temperature (95°C). Aliquots of slurry, extracted at 1, 2, 4, 6, 8 and 10 hourly intervals were filtered and the residue and filtrate analysed by ICPOES for K, P, Al, Ca, Fe and Mg.

The ball-milled product showed minimal potassium (8%) leaching in citric acid, but near-total leaching of phosphorus in citric acid. However the ring-ground P80 25µm concentrate achieved a high 40% potassium extraction after eight hours with hot citric acid. Notably hot citric acid had comparable leach kinetics as hot sulphuric acid. This enhanced dissolution with ring-grinding may be due to mechanical activation, and prescribes follow-up leach tests on activated glauconite using mild-strength citric acid.

These follow-up tests however required considerably more sample than what was generated from the ten-sample composite.

### **Processing of Mini-bulk Sample**

A circa 200kg composite sample of glauconitic sandstone was collected from the boat landing locality on the banks of the Daly River (792112mE/8385039mN), where previous grab samples of sandstone had indicated modal content of 38% glauconite.

The primary purpose was to obtain a concentrate in order to undertake analysis and leach testing on activated concentrate. A secondary objective was to provide material for comparative pot-plant trials between activated and non-activated glauconite.

Unfortunately, concentration was attempted before quantitative metallurgical tests were undertaken to optimize grinding, classification and magnetic extraction parameters. Consequently only 12 kg of high-quality glauconite concentrates was obtained.

### **Activation of Glauconite**

Consideration has been given to both thermal and mechanical activation of glauconite concentrate, in order to enhance solubility of potassium and phosphorus. Initial tests are being trialled on a proprietary thermal activation technique.

The concept of thermal activation relates to the presence of the hydroxyl molecule in glauconite; this would be expelled on heating thus creating crystal lattice instability and molecular-scale porosity, which would in turn enhance leaching.

## NAC Analysis of Activated Glauconite

The NAC (neutral ammonium citrate) analysis is a standard commercial technique for agricultural fertiliser, generally applied to phosphate fertilisers. It measures the amount of elemental material that is available for plant uptake over an unspecified period of time. Four grind sizes of three trial activation states were subject to one-hour shaking in 2% neutral ammonium citrate at 65<sup>0</sup>C. Initial indications are that potassium leached from activated glauconite shows a twelve-fold increase relative to non-activated glauconite. Also leaching is largely independent of grind size size.

The best result is tabulated below with respect to non-activated material, showing percentage dissolution of potassium and phosphorus.

Element	State	1hr NAC mg/kg	10hr NAC mg/kg	Head %	% Yield 1hr	% Yield 10hr
Potassium	Non -activated	420		5.84	0.7	
	Activated	5,341	5,886	5.84	9	10
Phosphorus	Non-activated	361		0.56	6.5	
	Activated	843	3,577	0.56	15	87

### NAC analysis of activated and non-activated glauconite

Thus 10% of elemental potassium is available from activated glauconite using a 10-hour shake test in weak ammonium citrate. The potassium result equates to 0.5 – 0.6 K in conventional fertiliser specification terms. The NAC analysis also confirmed the high yield in phosphorus after 10 hours.

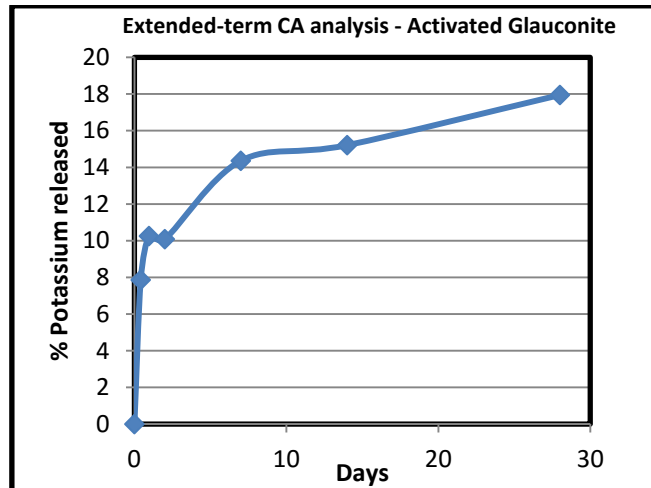
## CA Analysis of Activated Glauconite

The CA (Citric Acid) analysis is another standard agricultural fertilizer analytical method to indicate the amount of essential element that is available for plant uptake in neutral soils. As with NAC it is generally applied to phosphorus but can be applied to potassium. For general fertilizer specification it is mostly done at a weak 2% acid concentration, at ambient temperature, over a one-hour shaking period.

Activated glauconite has been subject to customized CA analysis over much longer periods of shaking time using relatively dilute 5% citric acid. Results are tabulated and graphed below. They show an initial short-term release of 10% of the available potassium in the first 10 hours (0.4 days), and then a slow steady release of 18% of available potassium after 28 days. This slow release phase appears to be linear, and a projection of line indicates near total release of contained potassium (6%) after about 300 days. and should help define the amount of slow-release potassium available for plant uptake over a period of time approximating an annual plant-growing cycle. Further long-term CA tests are required over periods of two and four months to quantify this slow-release estimate. Notably all phosphorus is released quickly.

Leach time days	Potassium analysis	%K dissolution	Phosphorus analysis	% P Dissolution
0.4	0.46	7.9	0.52	92.9
1	0.60	10.3	0.57	101.8
2	0.59	10.2	0.50	89.3
7	0.84	14.5	0.53	94.6
14	0.89	15.3	0.53	94.6
28	1.05	18.1	0.55	98.2

Extended-term CA analysis of activated glauconite

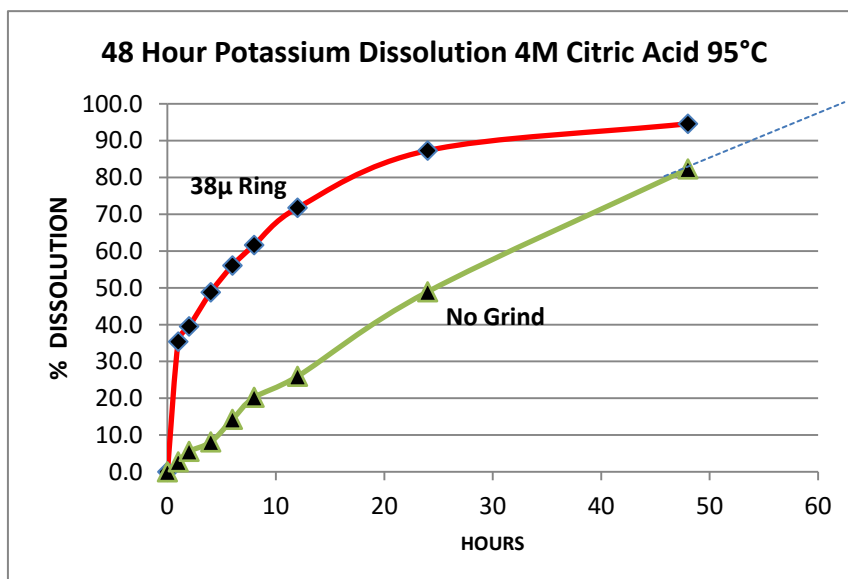


## Kinetic Leach Test on Activated Glauconite

Kinetic leach tests were conducted over an extended period of 48 hours at 95°C. Two size fractions were used:

- As received (48µm-106µm) to replicate an initial 10-hour test, and
- Ring-grinded to P80 38µm to replicate the encouraging result from the earlier CSIRO test.

Time-series graphs are presented below. The potassium dissolution is based on 7.74% K<sub>2</sub>O which is the head of the actual material used in the kinetic leach tests.



These results indicate:

- 82% dissolution of potassium after 48 hours from the 48-106  $\mu\text{m}$  fraction and the curve is rising as a straight line. On this trajectory, close to 100% leaching would be achieved at 60 hours:
- 95% dissolution of potassium after 48 hours from the fine ring-grinded material, with the leach curve tailing off towards 100%.

Most of the potassium and all the phosphorus dissolves quickly in citric acid. This indicates that re-grinding or fine-grinding may not be necessary in a commercial production. The dissolution of iron and magnesium comes out with potassium and phosphorus, particularly in the coarser fraction.

Further kinetic leach tests are required to determine dissolution parameters of all elements under more benign conditions such as lower temperature, lower acid strength, enzyme catalysts, and finer grind size.

## Conclusions and Recommendations

Conclusions from Year 1 work are:

- The proprietary activation process successfully enhanced the dissolution of Florina glauconite for potassium and phosphorus.
- Neutral ammonium citrate (NAC) analyses of activated glauconite show a twelve-fold increase in leachability of potassium, compared with non-activated glauconite.
- Extended-term citric acid (CA) analyses suggest that near-total release of elemental potassium may be achieved over a period of an annual plant growing cycle.
- Kinetic leach tests on activated glauconite with hot citric acid shows 82% dissolution of potassium after 48 hours from the 48-106 $\mu\text{m}$  size fraction, and the curve is still rising; on this trajectory, close to 100% leaching would be achieved after 60 hours.
- Kinetic leach tests show citric-acid leaching may selectively dissolve potassium and phosphorus, but significant aluminium, iron and magnesium dissolution is also achieved.
- Leach results demonstrate Florina glauconite may deliver either a slow-release potassium fertiliser with phosphate credits, or feedstock for industrial potash with phosphate and sulphates as by-product.
- Further kinetic leach tests will be required to optimize the extraction of potassium in terms of temperature, acid strength, leach time, grind-size of feed and catalysts; such tests would define the preferred product path.
- The next imperative is to understand the grade distribution within the Florina glauconite sandstone, which can only be done by a two-hole core-drilling program; this will provide controlled material for further metallurgical tests and resource estimation.

Recommendations for further work:

- Drill two PQ (85mm) core holes through the LGS at localities 5km apart, to understand the vertical and lateral distribution of glauconite and phosphorite grade. This will give an understanding of the thickness of glauconite-rich beds as they may relate to selective mining units.

- Construct geological and resource models, and estimate an inferred resource from the two Stratigraphic/metallurgical holes.
- Measure the geotechnical parameters of the potential orebody by tests on drill core, to estimate mining and beneficiation costs.
- Quantify the amount and timing of potassium available for plant up-take from various forms of processed glauconite by further plant trials and industry-standard analysis suitably customized for the specific products.
- Undertake further kinetic leach tests to optimise potassium and phosphorus extraction, in regard to organic acid strength, temperature, grind size, differential leaching and fungal catalysts.
- Design preliminary process flowsheets and mass balances for downstream processing by the sulphate and carbonate routes for the production of chemical potash.
- Commission a market and price study for the predicted products by an independent industry expert

## References

- Kruse PD, Tickell SJ, Munson TJ, 2012. Florina formation: a new Ordovician unit capping the Daly Basin succession. Central Australian Basins Symposium 3
- McDonald RG, Jeffery CA, 2015. Hydrometallurgical options for extraction of (glauconite) green sands. Private report by CSIRO Mineral Resources Flagship to Tracker Geoservices Pty Ltd
- Peitsch BA, 1983. Explanatory Notes for Darwin 1:100 000 Geological series Sheet 5073, Northern Territory Geological Survey.
- Potash West 2013. Dandaragan Scoping Study Jan 2013
- Sharma T 1997. Extraction of potassium from glauconite. National Metallurgical Laboratory of India. Technical Journal v39, p151-156.
- Tickell SJ 2010. Daly Basin drilling 2010. Water Resources Division Northern Territory NRETAS. Technical Report 24/2010
- Townend Mineralogy. 20 Oct 2014. Report on glauconite separation from sandstone. Ref 23728
- Townend Mineralogy. 20 Oct 2014. Report on glauconite separation from sandstone. Ref 23757
- Townend Mineralogy. 26 mar 2015. Preparation of glauconite concentrate from rock samples. Ref 23807
- Verde Potash Plc 2014. Pre-Feasibility Study, Cerrado Verde ThermoPotash Project, Minas Gerais State, Brazil. NI 43-101 Technical Report, SEDAR