The Callista rare earth element project – discovery and characterisation of regolith-hosted mineralisation, Southwark granite suite, western Arunta region

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The important role of critical metals in clean energy technologies has increased interest in exploration for rare earth element (REE) deposits of all kinds, and in particular, regolith-hosted REE deposits with potential for economically favourable REE extraction pathways. The best-known REE-in-regolith deposits are the ionic-adsorption on clay (IAC)-style of REE mineralisation, as exemplified by deposits in southern China, but other REE-in-regolith styles with different mineralogies and extractabilities are recognised. The latter includes the weak acid extractable (WAE)-style, of which a number of examples are known in Australia.

Both IAC and WAE deposits are developed on weathered and altered granitic rocks; they typically have grades of 0.03 to 0.5% total rare earth oxides (TREO) and are leachable with mild reagents. WAE-style deposits differ from the IAC-style in that the REEs are more tightly held, probably largely within various secondary, fine-grained REE minerals, and require leaching with dilute acids (hydrochloric acid being particularly effective) rather than desorption agents to extract their REE inventory.

GSW Resources Pty Ltd identified the incompatible element-enriched Southwark granite suite of the western Arunta region (Proterozoic Aileron Province; **Figure 1**) as having potential for hosting REE mineralisation in granite-derived regolith materials. Subsequently, Exploration Licence (EL) 33195 in the MOUNT DOREEN 1:250 000 map area was acquired to explore for this mineralisation style. The targeting approach used here involved the following phases of prospectivity analysis:

- Regional-level targeting – selection of incompatible element enriched (IEE) terrains with developed regolith, ie mainly Proterozoic granitoid-dominated terrains containing 'hot' or high-heat producing, radiometrically anomalous granites, such as the Southwark granite suite.
- Initial prospect-level targeting – as enrichments in Th and/or U broadly correlate with REE abundance in granites and their derived weathering products, radiometric survey imagery was used as the primary tool to identify areas of prospective REE-enriched surficial regolith (**Figure 2**); this was combined with multispectral remote sensing imagery, including Sentinel scenes, to focus on exposed clay-rich soils.
- On-ground prospect-level targeting – follow-up geological investigations focused on regolith and landscape geology with geochemical soil sampling guided by ground radiometrics to identify anomalous concentrations of REE-in-soil.
- Lastly, ground truthing of prospect areas by drill testing.

Initial data from surface sampling on EL33195 indicated that exposed granitic saprolite was enriched in the REEs by a factor of about 2.6 times compared to unweathered Southwark granite. It was further noted that the REE inventory of the area was likely enhanced by the presence of microsyenite dykes and greisens, which are known late-

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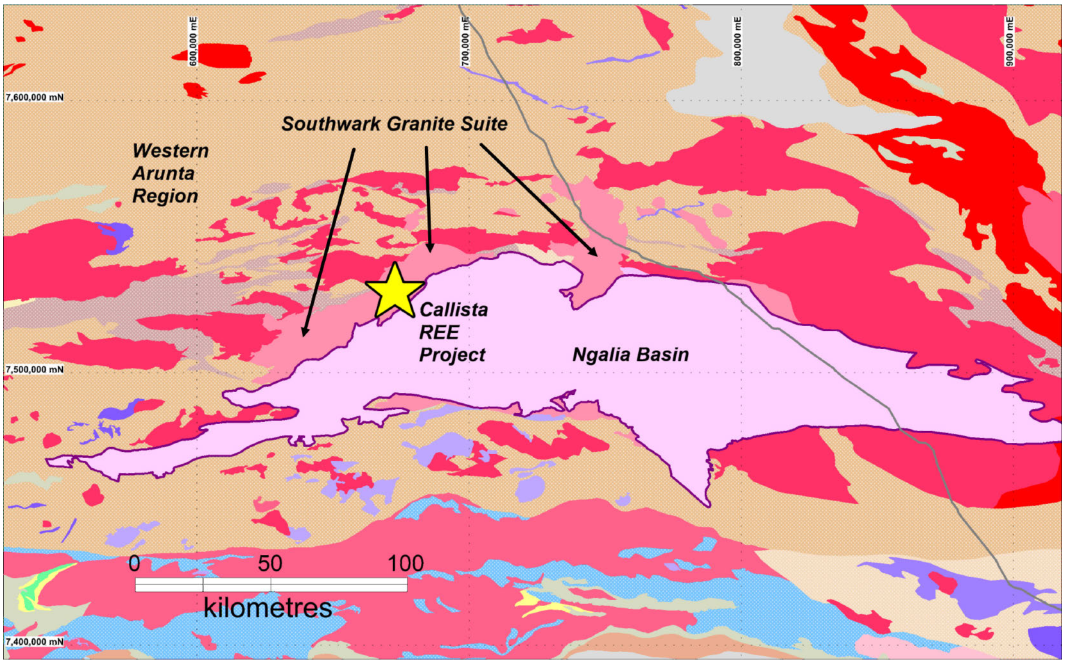

Figure 1. Location of the Callista REE project and Southwark granite suite in the western Arunta region, MOUNT DOREEN 1:250 000 mapsheet (MGA Zone 52).

stage components of the Southwark granite suite; these rocks are particularly rich in the HREEs and are susceptible to kaolinisation due to their high feldspar content. A further geochemical campaign outlined significant REE anomalies (>500 ppm TREO) in clay-rich soils, leading to the identification of three promising prospects: *Callista, Callista North* and *Thorntona* (located 12 km to the northeast of *Callista*), which collectively form the *Callista rare earth element project.*

At the *Callista* prospect, REE-bearing clays and minor granitic saprolite are exposed near surface due to the erosion of the silcrete cap (**Figure 3**). In central Australia, significant groundwater silcrete deposits formed at the base of palaeovalley/lake systems in Eocene–to-mid-Miocene times when climatic conditions were sub-tropical monsoonal (Alley *et al* 1999). The palaeoclimate would have been similar to that of southern China in Quaternary times when numerous REE-in-regolith deposits have formed on granite terrains. In the central Australian Cenozoic palaeovalleys, acidic waters percolated into the subsurface causing the weathering and clay alteration of the IEE Southwark granite suite.

Following the company's initial work, a successful application was made under Round 16 of the NT Geophysics and Drilling Collaborations program to fund an aircore drilling program to test the REE mineralisation potential of the prospects. No mineral exploration drilling of any kind had previously taken place on the tenement. The aircore drilling program, using a low-impact mobile rig, completed 122 holes for a total of 2902 m drilled. Average hole depth was 20 m at *Callista*, 31 m at *Callista North*, and 17 m at *Thorntona*. Drill spoil materials, consisting mainly of clay-

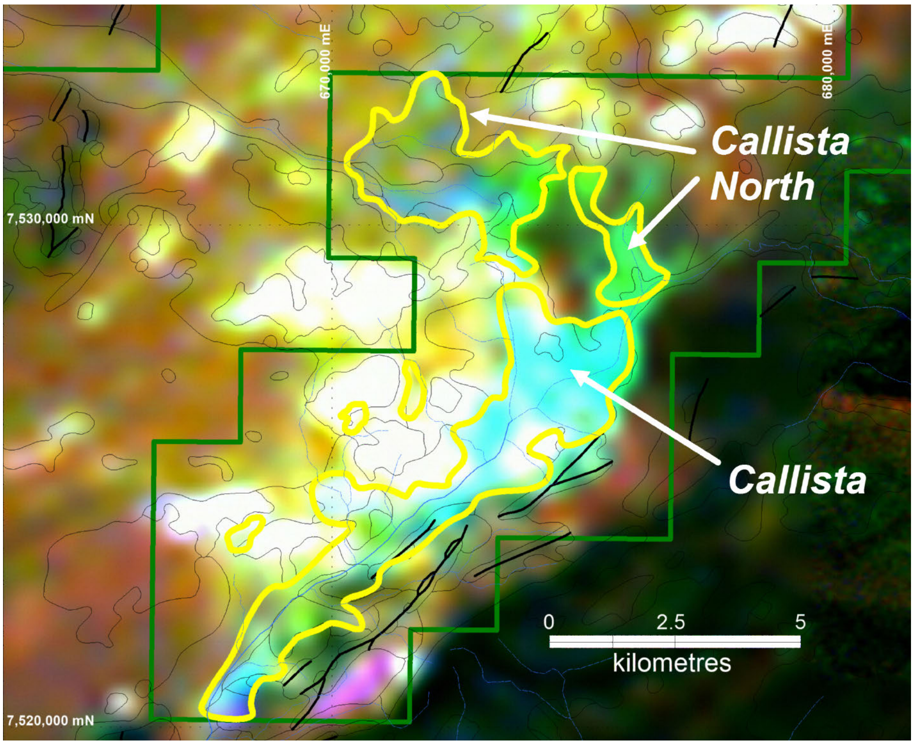

Figure 2. Radiometric RGB (K–Th–U) imagery showing surficial clay-rich regolith target areas (yellow outline) and associated Th (green), U (blue) and mixed Th–U (turquoise) anomalism.

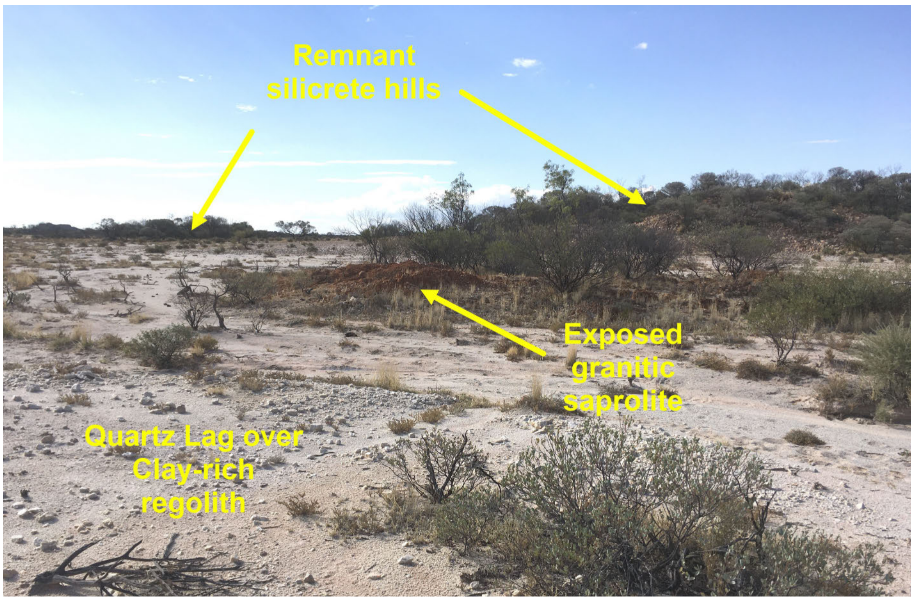

Figure 3. Landforms at the Callista prospect area.

rich granitic saprolite, were logged in the field; and single-metre or two-metre composite samples were sieved to -2 mm to remove coarse quartz and dispatched to the laboratory for assay by a microwave-assisted acid digest method. The results indicated the presence of significant thicknesses of REE mineralisation.

At the 900 ppm TREO cut-off level, average mineralisation thickness and grade is 17.5 m at 1851 ppm TREO for the *Callista prospect*, 18.4 m at 1503 ppm TREO for *Callista North*, and 10.2 m at 1470 ppm TREO for *Thorntona*. In terms of the valuable magnet REEs, NdPr-oxides are present at average grades of 328, 266 and 291 ppm, and DyTb-oxides at average grades of 47, 43 and 35 ppm, for *Callista, Callista North* and *Thorntona* respectively. The best intercept at *Callista* is from drillhole CA036 with 18 m at 0.45% TREO (747 ppm NdPr-oxides, 98 ppm DyTb-oxides). Significant mineralised intercepts are tabulated in **Table 1**.

Unmineralised or weakly mineralised cover amounts to only a few metres on average, with mineralisation often occurring from surface (**Table 1**). The results indicate that the Callista REE project is one of the highest grade REE-in-regolith prospects currently known from a granitic terrain in Australia; moreover, it contains superior levels of the valuable DyTb-oxides compared with other similar deposits.

In the regolith column, mineralisation typically straddles the boundary between light-coloured kaolinitic clays of an upper saprolite unit and darker grey to yellow-brown clays of a lower saprolite unit (**Figures 4–5**). Chemically, the upper saprolite is characterised by depleted rubidium (Rb) levels (<300–350 ppm) compared to the lower saprolite, which is more potassic and Rb-rich. The lower saprolite transitions into granitic saprock, which may be partly silcretised. Mineralisation is often but not always associated with a positive REE cerium (Ce) anomaly (Ce/Ce* >1, and >2 in some cases; **Figure 5**), which differs from the negative Ce anomalies seen in the REE-accumulation zones of IAC deposits (Borst *et al* 2022). In some holes, such as CA052, more than one strongly mineralised horizon is present. Other complexities include downhole variations in

Figure 4. Hole CA027 at Callista prospect. Note the thick interval of white kaolinitic clays of the upper saprolite unit (USAP).

Table 1. Significant REE-mineralised intercepts (TREO >45 000 ppm.m).

Hole ID	EoH (m)	Mineralised Interval (m)	TREO* (ppm)	from	Grade x Thickness (ppm.m)	Magnet REO (ppm)	NdPr Oxides (ppm)	DyTb Oxides (ppm)	Average Ce/Ce*
CA004	33	33	1,983	surface	65,434	394	352	42.0	1.232
CA010	23	23	2,400	surface	55,211	476	417	59.9	1.076
CA014	21	21	2,265	surface	47,569	449	390	58.5	0.924
CA015	21	19	3,208	2 m	60,953	675	603	71.5	0.927
CA027	33	25	2,093	8 m	52,335	392	341	51.0	1.302
CA036	18	18	4,489	surface	80,802	845	747	98.2	1.355
CA037	34	34	1,941	surface	66,003	363	309	54.0	1.441
CA042	30	30	1,859	surface	55,756	373	326	46.7	1.104
CA045	27	27	2,175	surface	58,714	450	389	61.0	1.090
CA050	18	18	2,640	surface	47,513	535	456	78.8	1.105
CA052	33	33	1,721	surface	56,797	343	304	39.8	1.066
CA053	29	29	1,826	surface	52,940	403	360	43.6	0.967
CA055	33	31	1,864	2 m	57,781	394	348	46.6	1.086
CA057	24	24	2,387	10 m	57,295	533	477	55.9	0.908
CA058	27	21	2,383	6 m	50,051	517	451	66.0	0.933
CA061	21	19	3,075	2 m	58,418	628	548	79.2	1.276
CN071	39	31	1,745	8 m	54,101	368	316	51.9	1.093
CN073	39	34	1,950	2 m	66,298	376	326	49.4	1.215
CN094	21	21	2,296	surface	48,208	529	459	69.6	0.854
CN098	45	31	1,718	14 m	53,252	351	304	46.7	1.174
CN100	34	28	1,851	6 m	51,826	367	308	58.8	1.136

*TREO = $La_2O_3 + CeO_2 + Pr_6O_{11} + Nd_2O_3 + Sm_2O_3 + Eu_2O_3 + Gd_2O_3 + Tb_4O_7 + Dy_2O_3 + Ho_2O_3 + Er_2O_3 + Tm_2O_3 + Yb_2O_3 + Lu_2O_3 + Y_2O_3$. Magnet REO = $Pr_6O_{11} + Nd_2O_3 + Tb_4O_7 + Dy_2O_3$.

CA027

From (m)	To (m)	Scint (cps)	Lithology	Colour	UNIT	Rb (ppm)	TREO (ppm)	Ce/Ce*
0	1	95	CYSD	pk	SOIL			
1	2	100	CGSP	pkwh	USAP	67.4	943	1.061
2	3	95	CGSP	wh	USAP			
3	4	110	CGSP	wh	USAP	84.8	879	1.033
4	5	110	CGSP	wh	USAP			
5	6	105	CGSP	wh	USAP	66.2	1011	1.14
6	7	105	CGSP	whyl	USAP			
7	8	100	CGSP	wh	USAP	41.2	804	1.079
8	9	105	CGSP	wh	USAP			
9	10	100	CGSP	wh	USAP	57.4	1408	1.403
10	11	100	CGSP	wh	USAP			
11	12	100	CGSP	wh	USAP	69.9	1938	1.237
12	13	100	CGSP	wh	USAP			
13	14	95	CGSP	wh	USAP	66.6	1537	1.348
14	15	100	CGSP	wh	USAP	46.1	1683	1.742
15	16	110	CGSP	wh	USAP	64.3	2696	1.687
16	17	110	CGSP	wh	USAP	72.2	2230	1.631
17	18	105	CGSP	wh	USAP	81.6	2716	1.648
18	19	100	CGSP	wh	USAP	90.9	1688	1.555
19	20	105	CGSP	wh	USAP	75.2	2250	1.413
20	21	105	CGSP	wh	USAP	82.3	3085	1.382
21	22	100	CGSP	wh	USAP	70.2	2182	1.368
22	23	105	CGSP	wh	USAP	62.8	3008	1.307
23	24	105	CGSP	wh	USAP	67.2	2575	1.318
24	25	110	CGSP	wh	USAP	83.8	2495	1.236
25	26	105	CGSP	wh	USAP	95.2	1610	1.284
26	27	100	CGSP	wh	USAP			
27	28	110	CGSP	ltgy	LSAP	169	1670	1.100
28	29	105	CGSP	ltgy	LSAP			
29	30	115	CGSP	ltgy	LSAP	397	1380	1.153
30	31	105	CGSP	ltgy	LSAP			
31	32	115	CGSP	gy	LSAP	476	3022	0.774
32	33	110	CGSP	gy	LSAP	524	2208	1.076

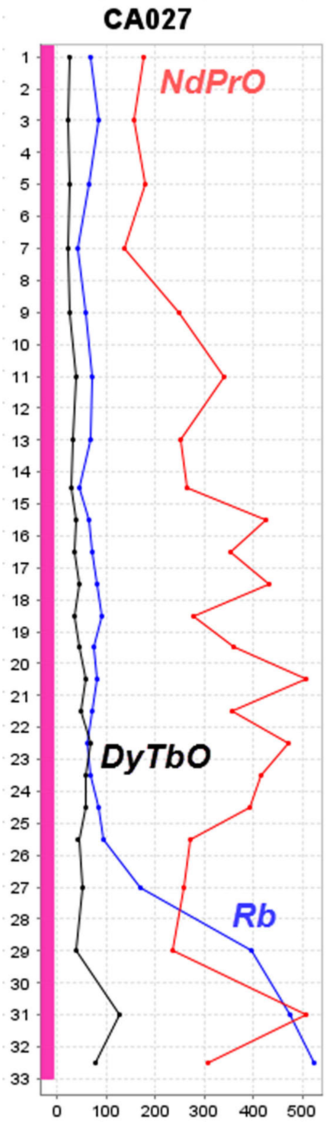

Figure 5. Hole CA027 downhole logging example. Note the thick mineralised interval of >1300 ppm TREO (yellow-red). High-grade intervals >2600 ppm TREO occurring within the upper saprolite unit (USAP) are associated with significant positive Ce-anomalies (Ce/Ce* >1.3). In contrast, the high-grade interval within the lower saprolite unit (LSAP) is associated with a negative Ce-anomaly and an elevated DyTb-oxide (Dy_2O_3 + Tb_4O_7 ppm) to NdPr-oxide (Nd_2O_3 + Pr_6O_{11} ppm) ratio compared to the upper high-grade zone. Such features suggest the REE are mobile in the regolith column. Note the downhole change from low-Rb to high-Rb content, which is an effective chemical marker of the transition between upper and lower saprolite units. CYSD = clayey sand, CGSP = clay-rich granitic saprolite. Scint = downhole scintillometer readings in counts-per-second. Colours: pk = pink; wh = white; yl = yellow; gy = grey; lt = light.

the ratio of the light REE (La to Sm) to the heavy REE (Gd to Lu) and in the Y/Ho ratio (Y-anomaly). All these features suggest that the REE have been mobile to some degree in the regolith column.

Preliminary bottle-roll leach extractions were undertaken using 10% HCl for an initial assessment of REE extractability. Sixty samples were leached at 50°C for 6 hours (10% pulp density) resulting in an average 70% extraction of the magnet REEs. This is comparable to the average 68% extraction of magnet REEs obtained by OD6 Metals Ltd for 10% HCl leaches on samples from its Splinter Rock project (Esperance WA), which is a REE deposit of the WAE-style mineralisation. It is considered likely that the Callista prospects are also of this style. Additional metallurgical testwork and mineralogical studies are in progress to fully characterise the deposit and investigate potential for cost-effective REE extraction and processing pathways.

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