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The Lonnie niobium deposit and its relationship to faulting and metamorphism

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Abstract:

The Lonnie Nb deposit is spatially associated with the Wolverine Fault, which is in turn related to the Manson Creek Fault system. The Lonnie deposit is the third-most developed Nb prospect in British Columbia. In the larger Aley Carbonatite and Upper Fir deposits, the Nb and Nb±Ta zones are carbonatite-hosted. Historical work done on the Lonnie deposit suggests that the highest Nb grades are associated with quartz-free feldspathic rocks; nevertheless, carbonatite (metacarbonatite) zones also contain significant concentrations of Nb. Limited sampling, carried out in 2012, agrees with historical findings in these respects. It also indicates that metacarbonatites have similar chondrite-normalized REE patterns to quartz-free feldspathic rocks, fenites, and nearby outcropping limestone; however, they have the highest REE concentrations. Fenitization extends for more than 30 metres from the complex southwestward into the host rock, perpendicularly to the strike of the Lonnie mineralization and the projection of the Wolverine fault. Carbonatite emplacement predates 4 periods of tectonic activity and the upper-amphibolite grade metamorphic climax. Pyrochlore is the main Nb-bearing mineral within aegirine-bearing metacarbonatite; however, it is absent, or a trace constituent in quartz-free feldspathic rocks - suggesting that Nb mineralization is present as columbite-series minerals or fersmite. Microprobe analysis is needed to confirm the presence and nature of these ore minerals. The adjusted Wolverine Fault Zone, as shown here, is probably the main Nb metalotect in the area; it aligns with a recently-available magnetic survey. Geochemical anomalies identified by Rara Terra Minerals Corp. at the Vergil carbonatite complex also appear to be located on the re-interpreted projection of the Wolverine fault.

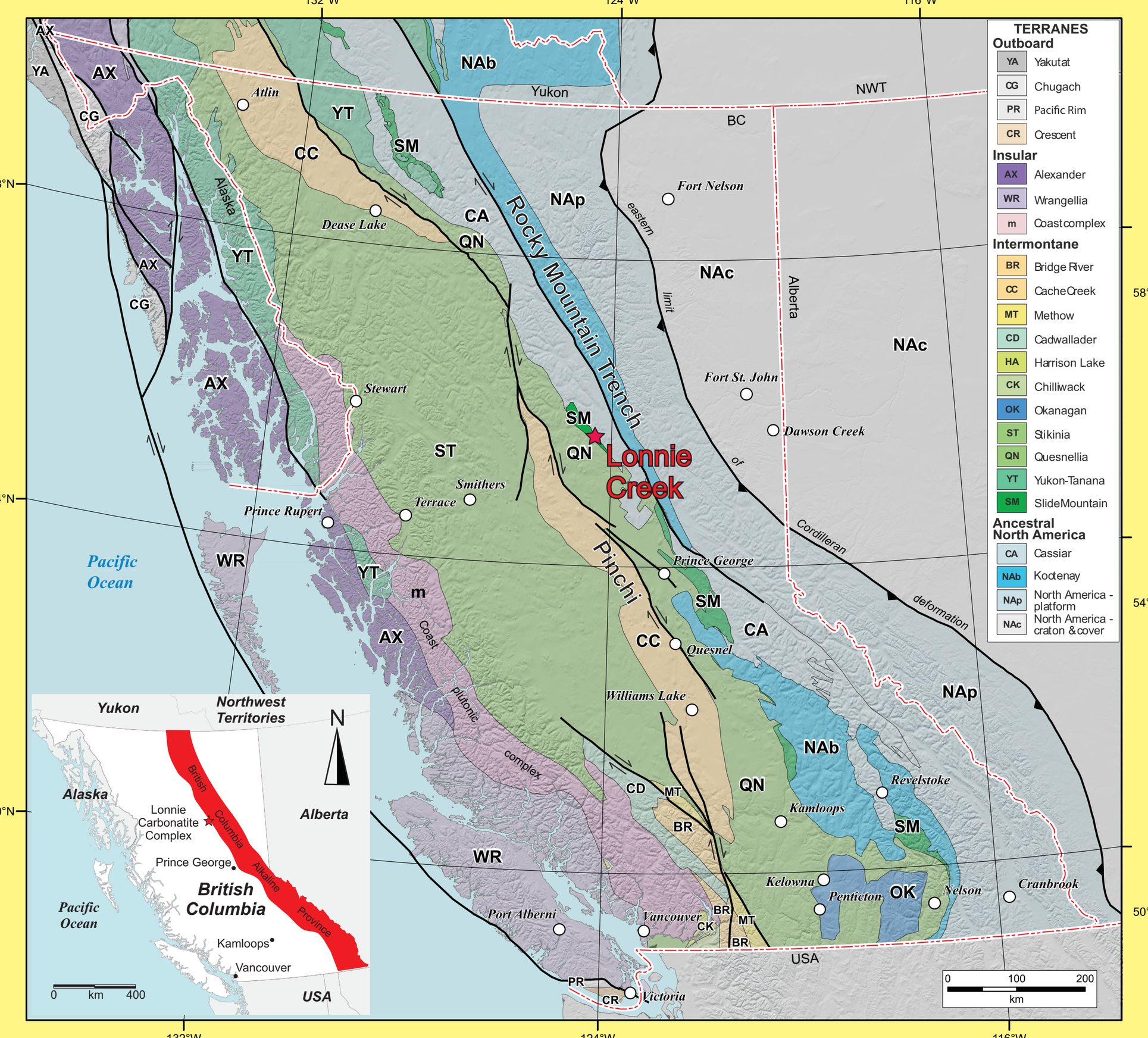


Figure 1. Location of the Lonnie carbonatite complex in central British Columbia. Modified from Colpron and Nelson (2011).

Introduction:

The Lonnie deposit, currently operated by Rara Terra Minerals Corp, is a carbonatite-syenite complex located in central British Columbia. It was discovered in 1953, and has been the subject of intermittent Nb-related (and more recently, REE-related) exploration activities from 1955 to the present day. It is located on the edge of the British Columbia Alkaline Province (Figure 1), southeast of the nearby Manson Creek settlement.

Niobium and the REEs are important strategic materials, necessary for component manufacture in various high-tech industries, steels, and superalloys (Simandl *et al*., 2012). Limited sampling was carried out in 2012 on a major outcrop oriented perpendicularly to the strike of the complex, as well as on the surrounding host rocks. This particular deposit was chosen as a study target for the specialty metals component of the TGI-4 because it represents an unusual type of mineralization; unlike the more conventional Upper Fir and Aley carbonatite-related Nb deposits, Nb concentrations are higher in associated quartz-free feldspathic rocks than the carbonatite itself.

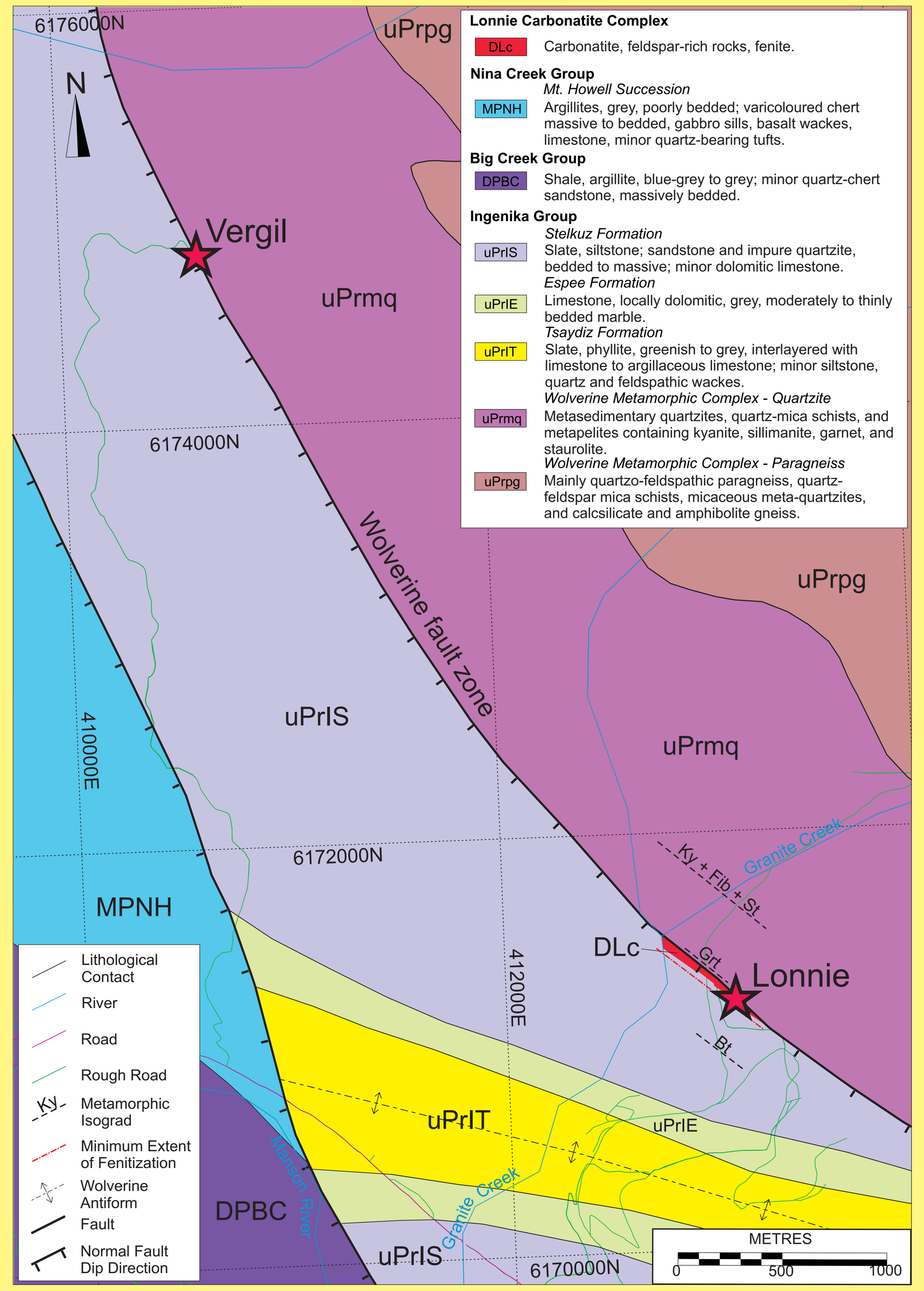


Figure 2. Lithological map of Lonnie-Vergil area and the Wolverine Fault Zone. After Ferri and Melville (1994). Metamorphic index minerals are on the high side of the isograd. Bt = biotite, Grt = garnet, St = staurolite, Fib = fibrolite, and Ky = kyanite.

Regional Geology and Metamorphic History:

The Lonnie carbonatite complex is bounded on the northeast by upper Proterozoic metamorphic rocks of the Wolverine complex, and to the southeast by the less-metamorphosed Stelkuz Formation. The limestones and marbles of the nearby Espee Formation form an excellent marker unit for delineation of structure in this area (Figure 2). The Wolverine fault zone is the principle feature dividing rocks of the Stelkuz Formation from rocks of the Wolverine complex. The original projection of the Wolverine fault zone, based on limited available outcrop data, traced roughly 750m to the east of the nearby Vergil deposit (Ferri and Melville, 1994). The results of a recent geophysical survey by Rara Terra (2013), have allowed us to reinterpret the projection of the Wolverine Fault Zone (Figures 2 and 3) which is likely the metallotect responsible for the Nb mineralization at Lonnie and the nearby Vergil deposit.

Ferri and Melville (1994) identified 4 major phases of regional deformation, spanning the Jurassic through the late Cretaceous/early Tertiary. The upper-amphibolite grade metamorphic peak occurred between the early and late Jurassic deformations: D1 and D2, respectively. The D3 event (early to middle Cretaceous) resulted in the development of the Wolverine antiform (shown in Figure 2). The D4 event (late Cretaceous to early Tertiary) is interpreted to have resulted in the formation of the Wolverine and Manson Creek fault zones.

The Lonnie complex itself is late Devonian to early Mississippian in age, based off zircon, U-Pb, and Pb-Pb dating (Pell, 1994). This predates the D4 event by over 300 Ma. The major observed displacement along the Wolverine fault occurred during the D4 event, but the Wolverine fault zone must coincide with a much older zone of weakness that controlled the emplacement of Nb-bearing carbonatites.

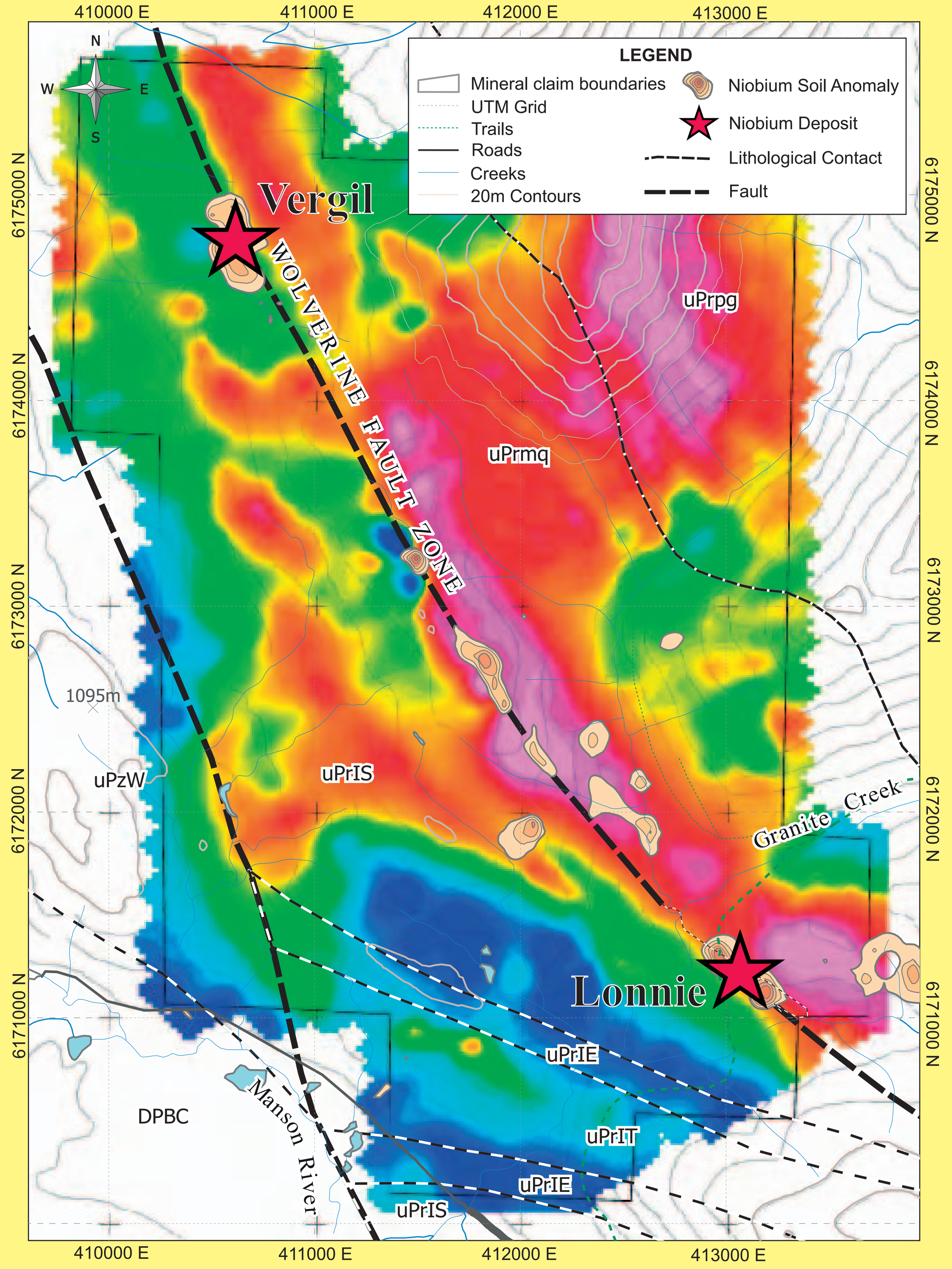

410000 E
411000 E
412000 E
413000 E
LEGEND
Mineral claim boundaries
UTM Grid
Trails
Roads
Creeks
20m Contours
Niobium Soil Anomaly
Niobium Deposit
Lithological Contact
Fault
Vergil
Lonnie
WOLVERINE FAULT ZONE
Granite Creek
Manson River
6175000 N
6174000 N
6173000 N
6172000 N
6171000 N

Figure 3. Magnetic map of Lonnie-Vergil area with the trace of the Wolverine Fault Zone superimposed, with Nb soil anomalies identified by Rara Terra. Known Nb mineralization shown by red stars.

Lithogeochemistry:

The Lonnie complex is a Nb ± REE exploration target. Quartz-free feldspathic units possess the highest Nb values (Table 1); sample 13 had Nb concentrations exceeding 2500 ppm. The next highest Nb anomalies were carbonatite from the heterogeneous zone (14C), the biotite carbonatite (10), and sample 15. Nb and REE concentrations are shown in Table 1. The exact mode of formation of sample 15 is a bit of mystery. It may be the result of K-Na liquid immiscibility, or the result of albitization under higher-than-usual SiO_2 concentrations.

Rocks from the Lonnie carbonatite complex and associated fenites display a typical chondrite-normalized carbonatite LREE-enriched pattern. The surrounding rocks display a similar, somewhat flattened pattern. These similarities suggest that the associated fenitization occurred as a result of the emplacement of the carbonatite.

	Biotite Carbonatite			Aeg ± Na-Am Carbonatite		Quartz-free Feldspathic Rock			Fenites		Fenitized Metasediments		
Sample:	09	10	10A	14C	14E	12	13	15	14B	14D	16	17	19
ppm													
Nb	312	1210	131.5	1670	291	617	>2500	939	236	140	369	193	1.3
La	328	570	489	506	354	69	147.5	383	172.5	205	54.3	176	3.7
Ce	580	1000	889	809	537	113.5	265	662	283	335	95.5	332	6.9
Pr	58.5	103	90.6	77.8	49.2	10.95	24.6	65	28.1	33.5	10.15	35.6	0.75
Nd	188	320	289	239	142.5	31.8	71.1	194.5	85.2	104.5	32.9	118	2.5
Sm	30.2	52.2	48.4	36.2	20.2	4.31	9.02	26	12.9	16.05	5.75	22.8	0.44
Eu	9.05	15.6	14.7	10.65	5.81	1.22	2.41	6.73	3.58	4.81	1.61	6.5	0.13
Gd	25.5	43.6	38.9	29.3	15.9	3.32	6.51	17.85	9.78	13.65	5.61	21.5	0.4
Tb	3.18	5.46	5.17	3.65	2.05	0.41	0.76	1.97	1.17	1.64	0.74	3.08	0.05
Dy	13.9	25.1	23.9	16.35	9.37	1.82	3.18	8.11	5.1	7.11	3.63	15.85	0.28
Ho	2.42	4.46	4.24	2.87	1.68	0.32	0.58	1.34	0.85	1.2	0.67	3.1	0.05
Er	6.09	11.35	11.15	7.37	4.47	0.85	1.6	3.46	2.09	2.98	1.87	8.84	0.15
Tm	0.83	1.62	1.59	1.05	0.66	0.14	0.27	0.51	0.31	0.45	0.31	1.38	0.02
Yb	4.37	9.11	9.03	5.85	3.98	0.74	1.6	3.01	2.07	2.74	1.92	8.03	0.13
Lu	0.68	1.49	1.49	0.98	0.72	0.13	0.29	0.53	0.45	0.56	0.36	1.33	0.02
Y	59.1	113.5	122.5	70.1	44.2	8.5	12.7	33.5	21.5	27.4	16.4	86	1.5
ΣREE	1250.72	2162.99	1916.17	1746.07	1147.54	238.51	534.42	1374.01	607.1	729.19	215.32	754.01	15.52
ΣREY	1309.82	2276.49	2038.67	1816.17	1191.74	247.01	547.12	1407.51	628.6	756.59	231.72	840.01	17.02

Table 1. Lonnie complex Nb and REE concentrations; chondrite-normalized REE concentrations are plotted in Figure 7. Data obtained by lithium metaborate fusion followed by inductively coupled mass spectrometry (LB-ICPMS) at ALS Laboratories in Vancouver. 2500 ppm (Nb) represents the upper limit of detection for this analytical procedure.

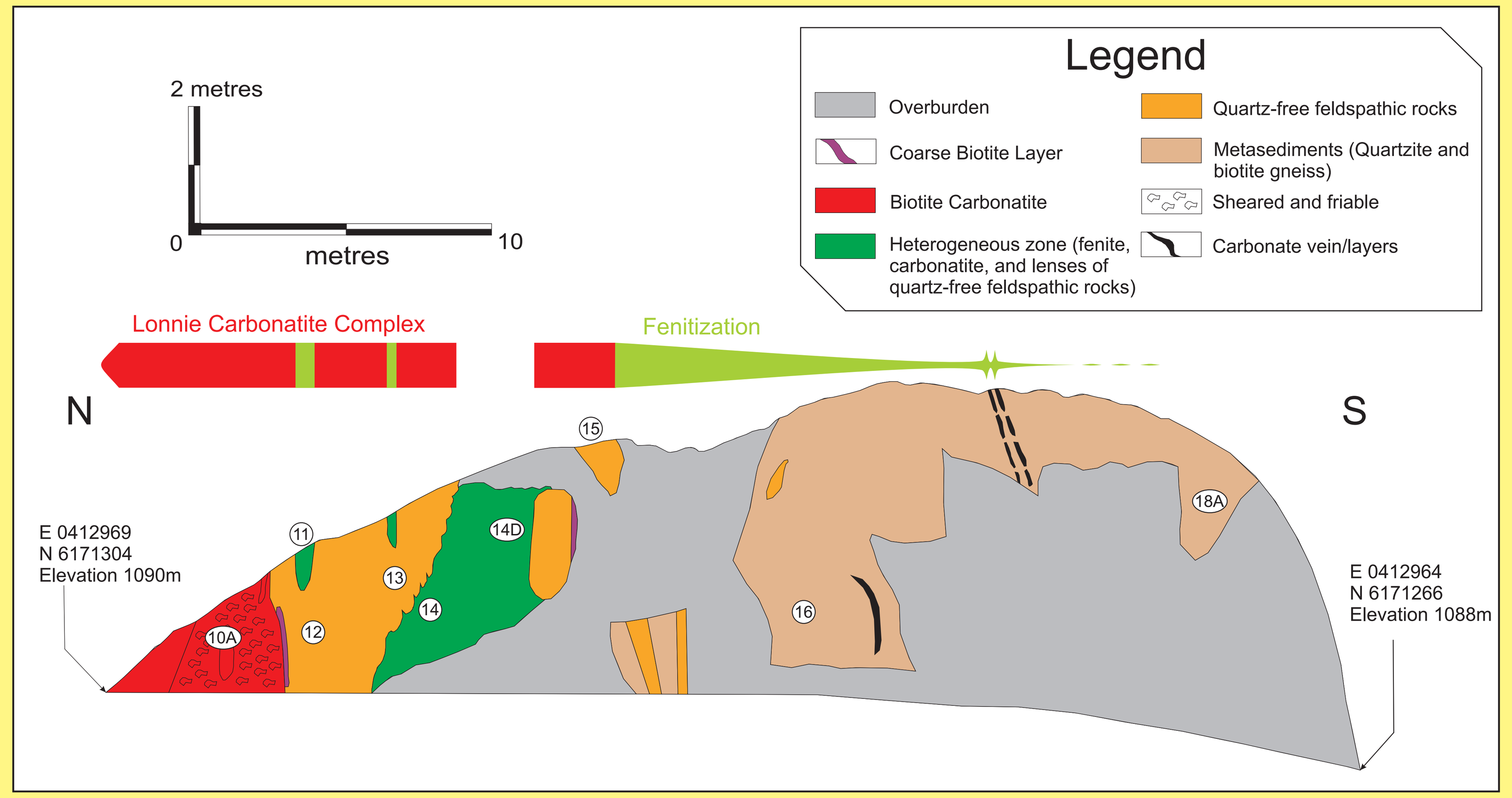

Legend
Overburden
Coarse Biotite Layer
Biotite Carbonatite
Heterogeneous zone (fenite, carbonatite, and lenses of quartz-free feldspathic rocks)
Quartz-free feldspathic rocks
Metasediments (Quartzite and biotite gneiss)
Sheared and friable
Carbonate vein/layers
2 metres
0
metres
10
Lonnie Carbonatite Complex
Fenitization
N
S
E 0412969
N 6171304
Elevation 1090m
E 0412964
N 6171266
Elevation 1088m

Figure 4. Sketch of the N-S oriented outcrop sampled in this study, looking east. Number identifiers correspond to sample numbers taken in the field, and are identified in Figures 5 and 6.

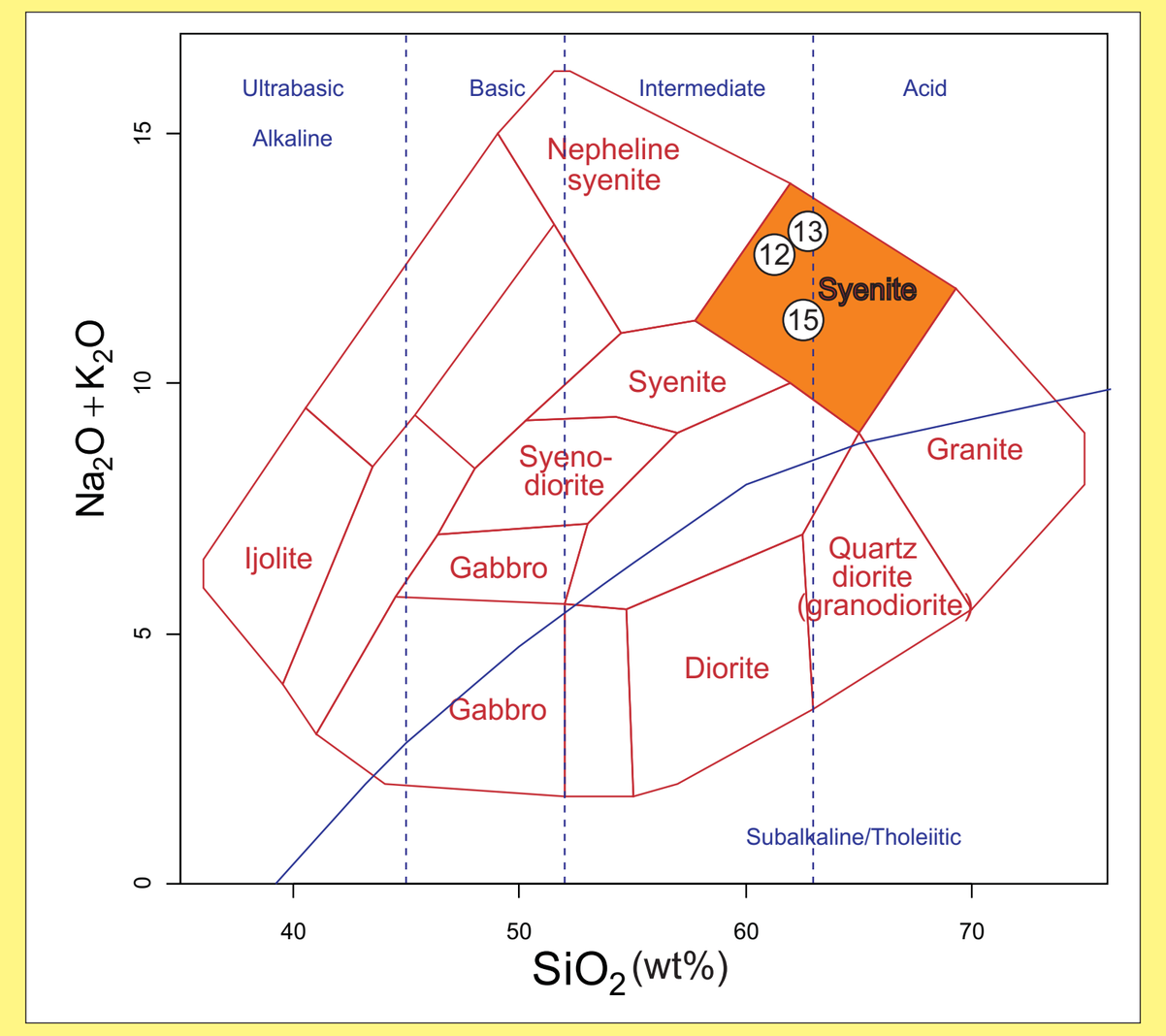


Figure 6. Total alkali-silica (TAS) diagram. Quartz-free feldspathic rocks plot in the syenite field. Sample 15 is composed primarily of plagioclase (and has a high Na/K ratio). Diagram after Cox (1979), and Wilson (1989).

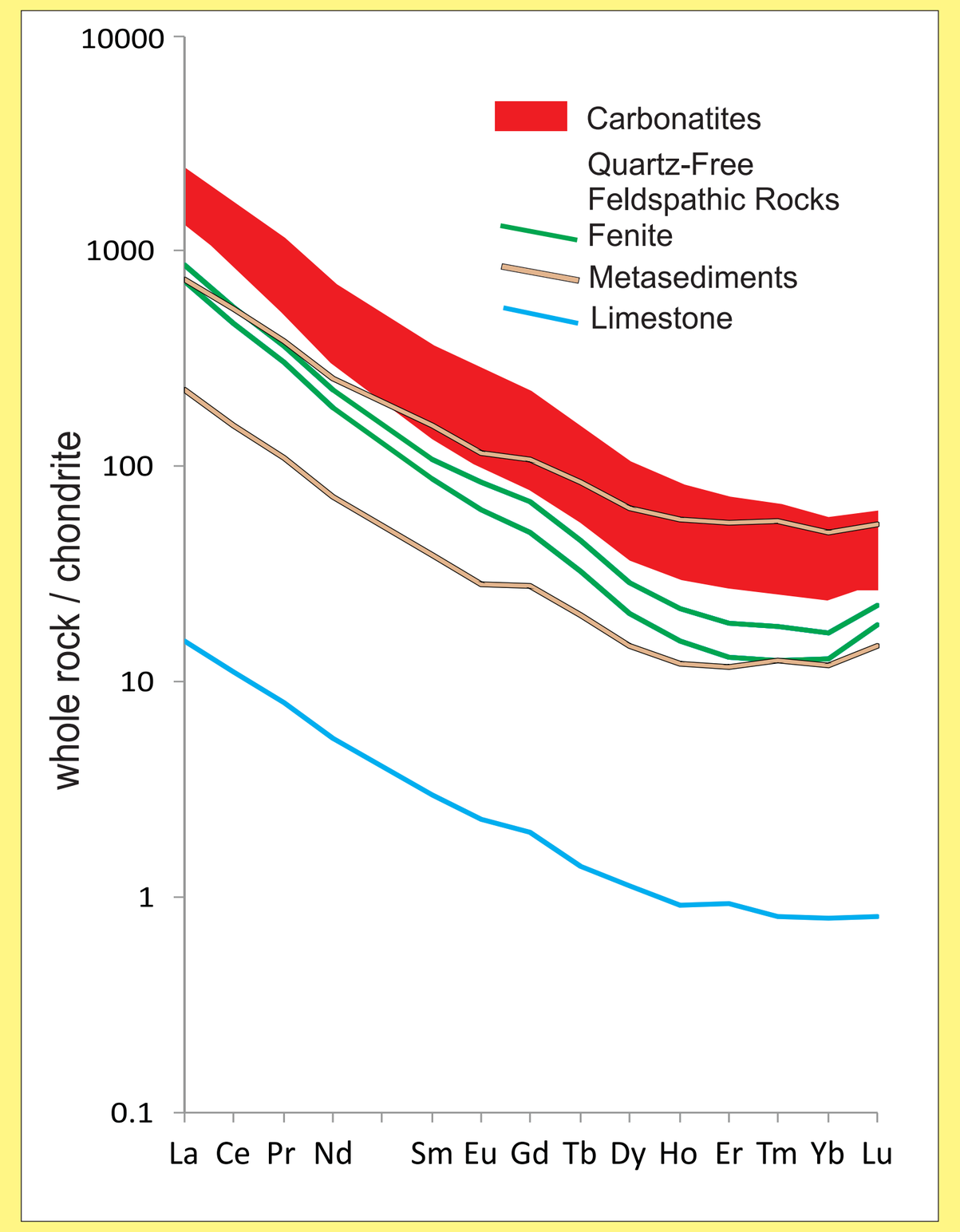


Figure 7. Chondrite-normalized REE profiles show similar patterns for all samples. Carbonatites have the highest ΣREE content, with syenites, fenites, and quartzites having progressively lower REE concentrations. Chondrite normalization values from McDonough and Sun (1995).

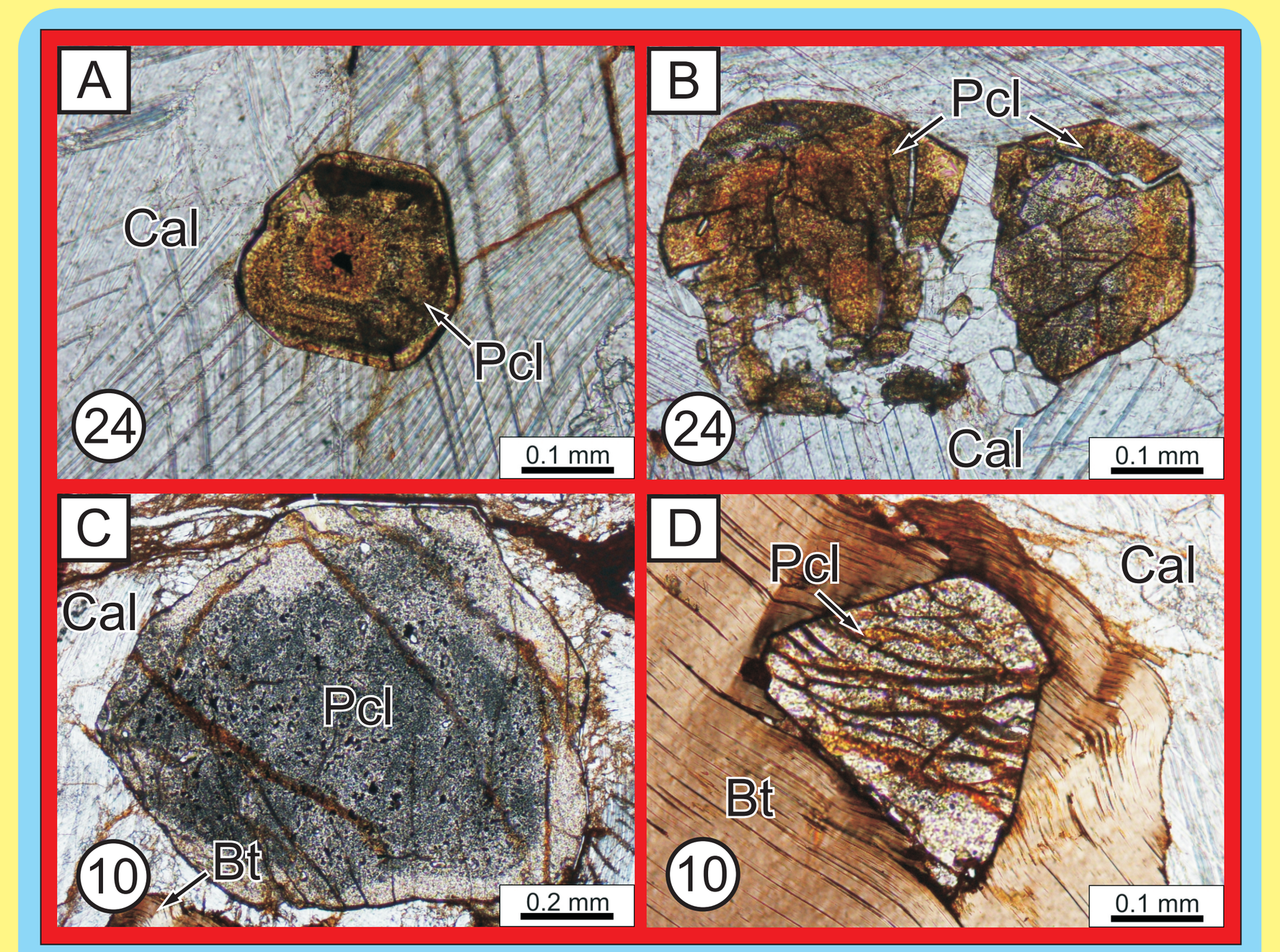
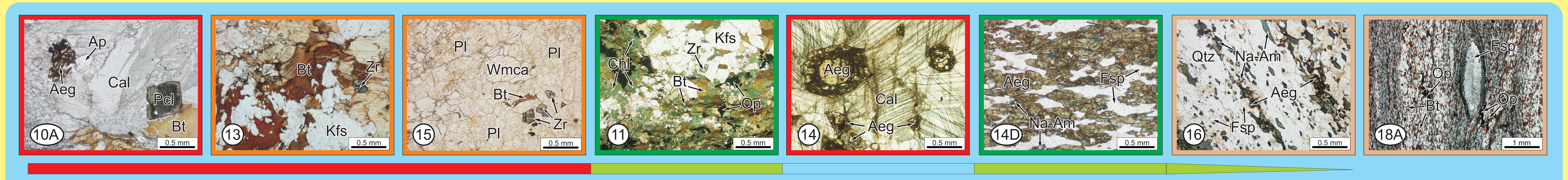


Figure 8. Pyrochlores from the Lonnie carbonatites Pyrochlore from aegirine carbonatite (sample 24) may be **a)** chemically and inclusion zoned; creating coloured and darkened bands, and **b)** appear broken and resorbed. This rock sample is composed of calcite (Cal) and aegirine, with accessory apatite, feldspar, pyrochlore (Pcl), and opaque minerals. Pale brown, subhedral pyrochlore from biotite carbonatite (sample 10) have inclusions darkening their cores, and are oxidized along fractures. Pyrochlore may be: **c)** apart or adjacent to biotite (Bt), or **d)** truncating biotite cleavages.



Sample 10A. Biotite-bearing calcite carbonatite. Pale brown pyrochlores (Pcl) display strong inclusion zoning. Calcite (Cal) and biotite (Bt) are the main constituents. Feldspar, apatite (Ap), pyrochlore, altered aegirine (Aeg), and opaques make up accessory minerals.

Sample 13. Nb-bearing quartz-free feldspathic rock, consisting mainly of potassic feldspar (Kfs), distincly reddish biotite (Bt), accessory zircon, interstitial calcite and opaque minerals. Columbite-series minerals or fersmite are the suspected Nb carriers.

Sample 15. Quartz-free feldspathic rock, composed almost entirely of plagioclase (Pl). It plots in the syenite field in Figure 5, but mineralogically, it is suggestive of an albitized syenite. Accessory minerals consist of potassic felsdpar and white mica (Wmca), along with accessory biotite (Bt) and euhedral zircons (Zr).

Sample 11. Altered quartz-free feldspathic rock. Euhedral zircons (Zr) are embedded in potassic feldspars (Kfs). Chlorite (Chl) is replacing biotite (Bt). Lathe-like subhedral opaque minerals (Op) are spatially associated with the chloritization. Euhedral pyrite supports a post-metamorphic overprint.

Sample 14. Aegirine carbonatite near carbonatite/fenite contact. This sample completely lacks blue-green sodic amphiboles; aegirine (Aeg) is the main ferromagnesian mineral (aegirine-calcite mosaic forms a rim around the large aegrine core). Calcite (Cal) is the main carbonate mineral.

Sample 14D. "Fenite", composed of aegirine (Aeg) and untwinned feldspars (Fsp), with minor sodic amphiboles (Na-Am).

Sample 16. Partially fenitized "quartzite" consisting of quartz (Qtz) and feldspar (Fsp), as well as accessory aegirine (Aeg) and sodic amphiboles (Na-Am). Metamorphic layering may coincide with sedimentary features of the protolith.

Sample 14D. Fenitization-free biotite feldspar schist; country rock. Darker bands are the result of micron-scale sulfides (large sufides are marked Op), as well as a reduction in grain size. The sample contains biotite (Bt), and small amounts of white mica.

Figure 5. Petrography of the Lonnie carbonatite complex.
The fenitization scale below the pictures corresponds to the one in Figure 4.

Summary:

1. Nb mineralization is hosted by both quartz-free feldspathic rocks and carbonatites of the Lonnie complex.

2. Nb mineralization, soil Nb and [REE+Y] anomalies, and the magnetic signature coincide with the trace of the Wolverine fault zone.

3. Fenitization increases the width of the target, extending SW by more than 30m.

4. Both aegirine and sodic amphibole characterizes the fenitized zone. The Aegirine/Na-amphibole ratio decreases with increasing distance from the complex.

5. The Wolverine fault is a strong metallotect.

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References:

For a complete list of references, please consult:

Simandl, G.J., Reid, H.M., and Ferri, F. (2013): Geological setting of the Lonnie niobium deposit, British Columbia, Canada; In: Geological Fieldwork 2012, British Columbia Ministry of Energy, Mines and Natural Gas, British Columbia Geological Survey Paper 2013-1, pages 127-138.