

# FROGMORE COPPER DEPOSIT, NSW

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## LOCATION

The Frogmore Copper Mine is located 1 km S of Frogmore, approximately 200 km WSW of Sydney, at 34°16'26"S, 148°50'24"E; Goulburn SI55-12 1:250 000 and Boorowa 8629 1:100 000 sheets.

## DISCOVERY HISTORY

The Cu deposits of the Frogmore district were discovered and first worked in the 1860's. Copper sulphide mineralization in the intensely sheared Silurian Hawkins Volcanics was mined at the Frogmore Copper, Pride of Frogmore and South Frogmore mines; no production has been recorded since 1907. Exploration by several companies since the 1950s concentrated on areas of known mineralization, utilizing extensive geochemical, geophysical and drilling data in search for base metals and, more recently, Au. Rock chip, stream sediment and soil sampling, and RAB drilling of anomalies defined by airborne electromagnetic, radiometric and magnetic surveys have been used. In 1996, Michelago Resources NL drilled 14 reverse circulation (RC) holes into old workings and conducted soil sampling near areas of known mineralization to test the Frogmore and Pride of Frogmore mining areas (Willott, 1997). Extensive exploration has not led to new economic discoveries to date. Analysis of the exploration methods and subsequent results suggests that shallow bedrock sampling and soil sampling of anomalies identified by aeromagnetic and radiometric surveys may be the most appropriate exploration procedure.

## PHYSICAL FEATURES AND ENVIRONMENT

The mean daily maximum and minimum temperatures are 29-15°C (January) and 12-2°C (July). The annual rainfall of approximately 600 mm is evenly distributed throughout the year (Bureau of Meteorology, 2003). Annual evaporation (1600 mm) exceeds precipitation. The vegetation is predominantly Eucalypt and Acacia spp., with extensive grassland. Land use is primarily grazing of sheep and cattle and minor cultivation of cereals. Ephemeral drainage gullies traverse the mine sites and join a local network of creeks and ephemeral streams. The mine sites and previous exploration activities have since been reclaimed as part of a remedial environmental program.

## GEOLOGICAL SETTING

Frogmore is located in the Eastern Lachlan Fold Belt, in the Cowra Trough, which is dominated by a series of N trending Late Ordovician to Early Devonian volcanic, sedimentary and intrusive rocks (Figure 1). The Middle Silurian Hawkins Volcanics of the Douro Group host Cu sulphide mineralization and are coarse, porphyritic crystal-rich ignimbrites, volcanoclastics and sediments of dacitic and rhyolitic composition. Volcanoclastics and sediments of the Late Ordovician Kenyu Formation and a deep marine turbidite sequence of fine-grained sediments and shales of the Late Ordovician Phils Creek Formation unconformably underlie the host volcanics. Intruding these volcanics and sediments are the Licking Gully and Ballyhooley granites of the Late Silurian Wyangala Batholith (Figure 1).

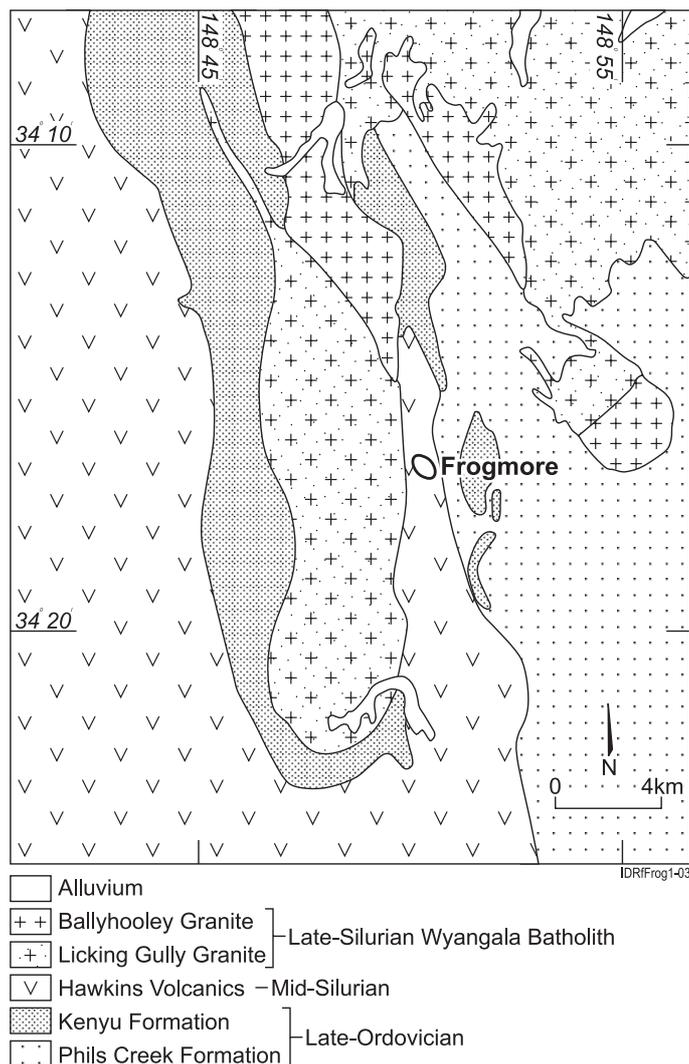


Figure 1. Local geology of Frogmore. Frogmore mine site indicated by ellipse.

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## REGOLITH

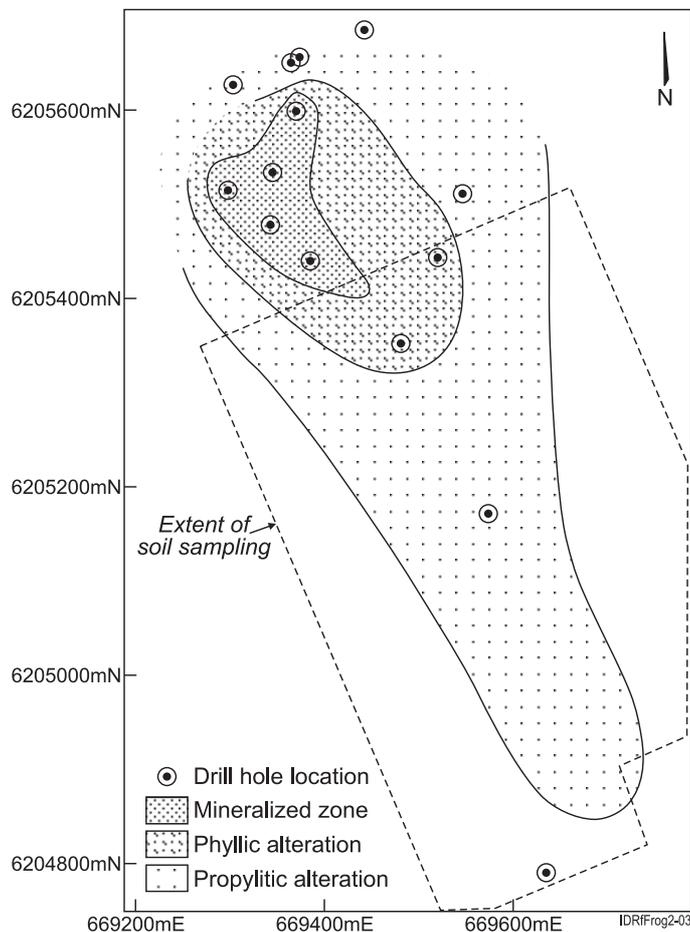


Figure 2. Estimated extent of mineralized and hydrothermal alteration zones surrounding the Frogmore copper deposit. The soil sampling grid and drill hole locations are shown.

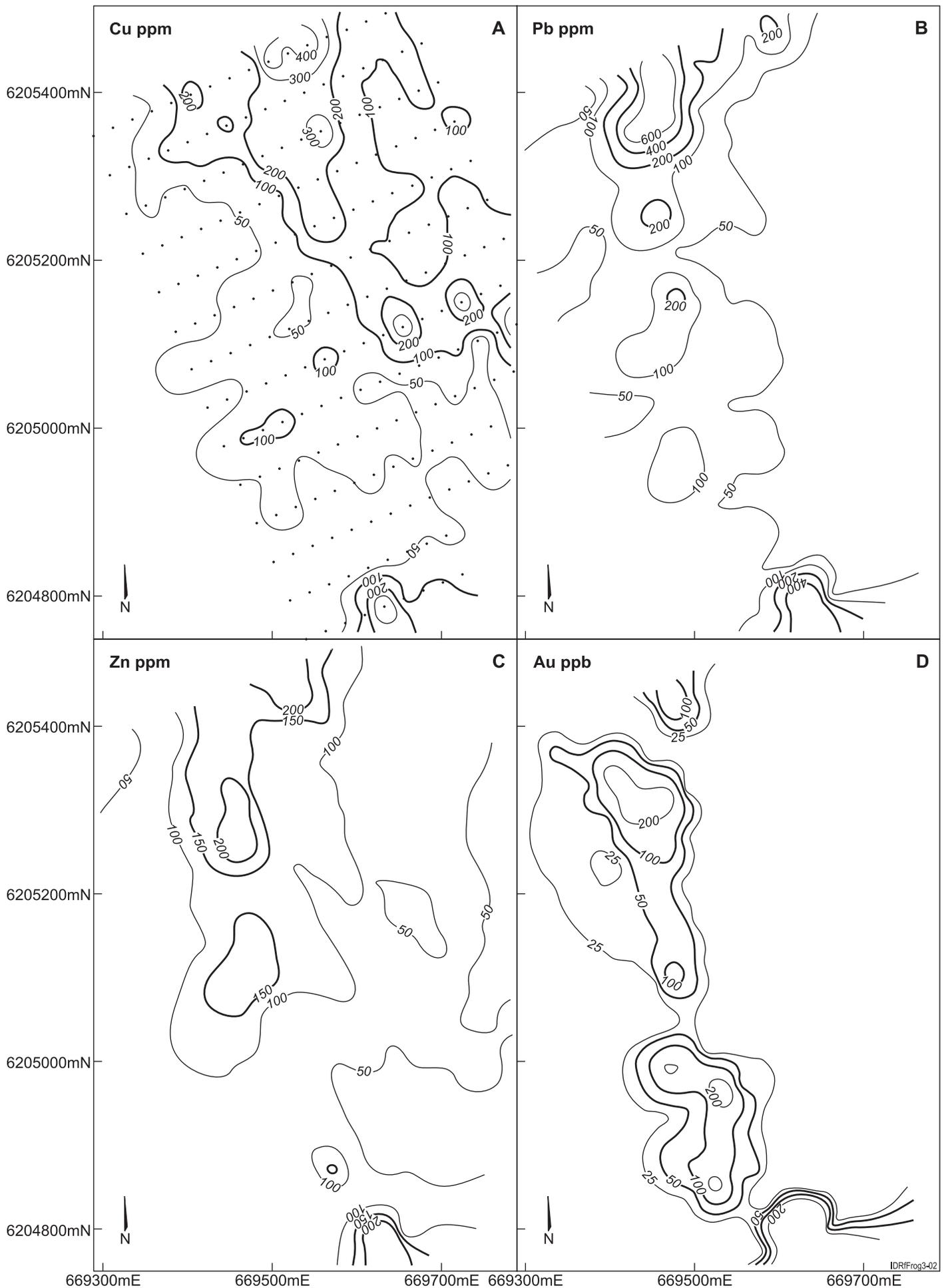


Figure 3. Anomalous zones identified by soil geochemistry for Cu (a), Pb (b), Zn (c) and Au (d) centred about 669520mE 6205450mN (AMG). Note the significant anomalous Au region at the southern end of the sampling grid.

In the Frogmore area, the landscape is dominated by N trending topographic highs and undulating low hills, which reflect resistant, silicified lithologies of the Hawkins Volcanics. The Frogmore deposit is on the northern side of the northern-most topographic high and has a local relief of up to 70 m. Drainage is to the S from the higher Wyangala Batholith. On the Hawkins Volcanics, skeletal, yellowish brown podzols have developed on the upper slopes. On the lower slopes and in topographic lows, soils are developed on thicker colluvium, alluvium and grey clays. Within the Frogmore mine area, soil sampling was confined to the upper horizons of residual soils. Outcrop is generally poor and consists of green to grey highly cleaved and intensely weathered dacitic rocks that are preserved on ridge tops and trend N. In creek beds and valley floors, saprolite occurs in washouts and drainage channels; there is very little outcrop of fresh bedrock. The depth of weathering in drill cores ranges from 15-25 m.

### MINERALIZATION

Narrow zones of quartz vein-hosted primary Cu sulphides at Frogmore occur within quartz porphyritic dacite. Ore samples show a chlorite-muscovite-biotite mineral assemblage within a groundmass of sericite and recrystallized quartz. There are multiple phases of sulphide, dominated by chalcopyrite and pyrite, with minor sphalerite and galena (Ackerman, 1999). Although there are some secondary Cu carbonates, there is no significant supergene enrichment.

The extent of the Frogmore deposit is not well defined. The main mineralized zone, intersected by the Michelago Resources NL drilling program, is thought to be elongated NW, dipping SE over a strike of at least 100 m (Willott, 1997). Although Cu concentrations reach approximately 13%, an estimate from mining records suggests an average grade of 11% Cu. Geochemical investigation of primary mineralization from mullock heap and drill chip samples showed a close association between the ore elements Cu, Pb, Zn and Fe, that define two mineralized zones at approximately 62 and 90 m depth. There is a close association between sulphide mineralization and Au, Ag, Sb, Co and Te, hence these elements are useful pathfinders.

### REGOLITH EXPRESSION

Zones of phyllic and propylitic alteration proximal to the mineralized zone (Figure 2) were identified by mineralogical and geochemical analysis in rock chip and drill spoil samples. Quartz, sericite, pyrite, minor chlorite, increased Fe and decreased Na and Ca characterize phyllic alteration, estimated to extend as much as 100 m from the mineralization. Propylitic alteration is more extensive, as shown by increased Mg and Fe and chlorite-epidote in rock chip samples for several hundred metres from mineralization.

Residual soil was sampled by Michelago Resources NL on the S side of Frogmore mine (Figure 2) to avoid contamination from the mining area. An approximate N-trending zone of anomalous Cu (>300 ppm), Pb (>400 ppm), Zn (>200 ppm) and Au (>150 ppb) (Figure 3) corresponds with the estimated southern extent of the mineralization (Figure 2). Copper is widely dispersed in residual soils, with concentrations above background (200 ppm) extending up to 200 m from the subcropping mineralization. A second zone of anomalous Au (up to 390 ppb) and lesser Pb, Zn and As, but low Cu (<50 ppm) suggests an alternative exploration target.

Sampling of saprolite was limited to two drill holes and several outcrops in the study area. Saprolite was significantly enriched in K (up to 2.7%), Rb (140 ppm) and Ba (920 ppm) relative to the unweathered rock. Ore-related elements, Cu and Zn, were detected in concentrations up to 77 ppm and 280 ppm respectively in the upper saprolite, although the pathfinder elements Au, Ag, Sb, Co and Te were not identified in any significant concentrations. Given the success of soil geochemistry at defining anomalous zones, it is expected that shallow drilling for saprolite would yield similar results.

In summary, a geochemical response to mineralization in residual soils is more broadly dispersed than in saprolite or rock chip samples, and is anomalous in Cu, Pb and Zn. A significant, but weak, progression of hydrothermal alteration zones is recognised in saprolite and rock chip samples surrounding the mineralization.

### ACKNOWLEDGEMENTS

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### REFERENCES

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- Bureau of Meteorology, 2003. [www.bom.au/climate](http://www.bom.au/climate).
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SAMPLE MEDIA SUMMARY TABLE

Sample Medium	Indicator elements	Analytical methods	Detection limits (ppm)	Background (ppm)	Threshold (ppm)	Maximum anomaly (ppm)	Dispersion distance (m)
Primary mineralization (ore elements)	Cu	XRF	5		2.42%	3.44%	<10
	Fe	INAA	20		6.12%	13.50%	?
	Pb	XRF	5		1.51%	2.41%	<10
	Zn	INAA	100		1820	3720	<10
Fresh Rock (pathfinders)	Ag	INAA	5	<5	8	32	?
	Au	INAA	0.005	0.17	0.26	0.39	<10
	Co	INAA	1	26	37	55	14
	Sb	INAA	0.2	2	2.8	5.8	10
	Te	INAA	5	<5	5	6	?
Saprolite	Cu	ICP-AES*	1	35	56	77	?
Soil	Au	ICP-AES**	0.001	0.1	0.16	0.39	90
	Cu	ICP-AES*	1	200	290	810	200?
	Pb	ICP-AES*	5	240	400	1440	80
	Zn	ICP-AES*	5	150	210	450	50

\* ICP-AES analysis after HClO<sub>4</sub> digest and HCl leach

\*\* AAS analysis after 50 g fire assay Pb collection and solvent extraction