of 98 m of 1.8 gm.t^{-1} gold was obtained but as the gold price was relatively low at that time no further work was done on the prospect till 1980.

Following recommendations from the project geologist and as a result of the spectacular rise in the gold price, a modest drilling program was begun in 1980. Drill hole number 12 cut 404 m of 2.7 gm.t^{-1} gold and the development of the Red Dome mine began. In order to complete the geophysical picture of Red Dome, gravity, ground spectrometer and two lines of 100 m time domain dipole-dipole IP were run on the prospect in 1983. The whole exploration licence area was flown with a close spaced airborne magnetics and spectrometer survey.

The gravity survey produced a marked low over the Red Dome deposit. This is due to the very low density of the oxidised breccia material near surface. The technique is not considered to be useful in exploration for further deposits as any such breccia would be more cheaply and easily recognised by geological mapping than by a gravity survey.

A wide spaced government aeromagnetic survey of the area had shown large remanent magnetic negative anomalies throughout the region with a tantalising correlation between these and old workings. A ground magnetic survey of the Red Dome prospect in the early stages of base metal exploration indicated that the andesitic beds and their associated unmineralised garnet skarns were strongly negatively magnetised. Henceforth, all negative anomalies were written off as barren andesite. When the Red Dome deposit was extensively drilled, approximately five years after the original ground magnetometer survey, the question of why the magnetite rich high grade porphyry skarn seen at depth did not produce a surface magnetic anomaly was raised. Re-examination of the ground data showed a very clear deep anomaly caused by this material. It had not been previously recognised since, like the barren andesite skarn, it is negatively magnetised. Crude tests on core samples reveal a dominance of remanence over induced effects of between 2 and 10 times.

Two lines of 100 m dipole-dipole time domain IP were run over the deposit to reveal a deep chargeability anomaly and resistivity high associated with the porphyry intrusion. The pseudo-sections are complicated by near surface responses, particularly from cherts adjacent to the deposit. Early frequency domain IP surveys did not detect the body as the dipole spacing was too small for the depth of weathering. IP can be considered an effective if somewhat expensive detection tool for Red Dome style mineralisation.

As expected, ground spectrometer data revealed a strong potassium anomaly over the outcropping porphyry and a somewhat weaker anomaly over the surrounding alteration. What was not expected however were four thorium anomalies, three of which lay exactly over the three main areas of known mineralisation. The fourth, subsequently drilled during engineering testing, lies over a narrow weakly mineralised porphyry. The reason for these anomalies is unclear, but is probably elevated thorium content within zones of clay alteration surrounding the mineralisation.

Regional geophysical exploration work in the area now relies on airborne magnetic and spectrometer data and their ground equivalents for follow up. In some areas IP can be considered as a further follow up tool.

THE GEOPHYSICS OF THE STARRA GOLD/COPPER DEPOSITS

Steve Collins

The Starra gold-copper deposits are contained in a quartz-hematite-magnetite ironstone within the Upper Proterozoic Staveley Formation approximately 150 km south east of Mt. Isa. (Figs 1, 2). The mineralisation is contained in the western limb of a north plunging synform. It occurs over a strike length of appoximately 6 km in a number of zones which are named according to their distance in hundreds of metres from the regional grid origin. Geologic reserves to date are 6 million tonnes of 5 gm.t^{-1} gold and 2 percent copper.

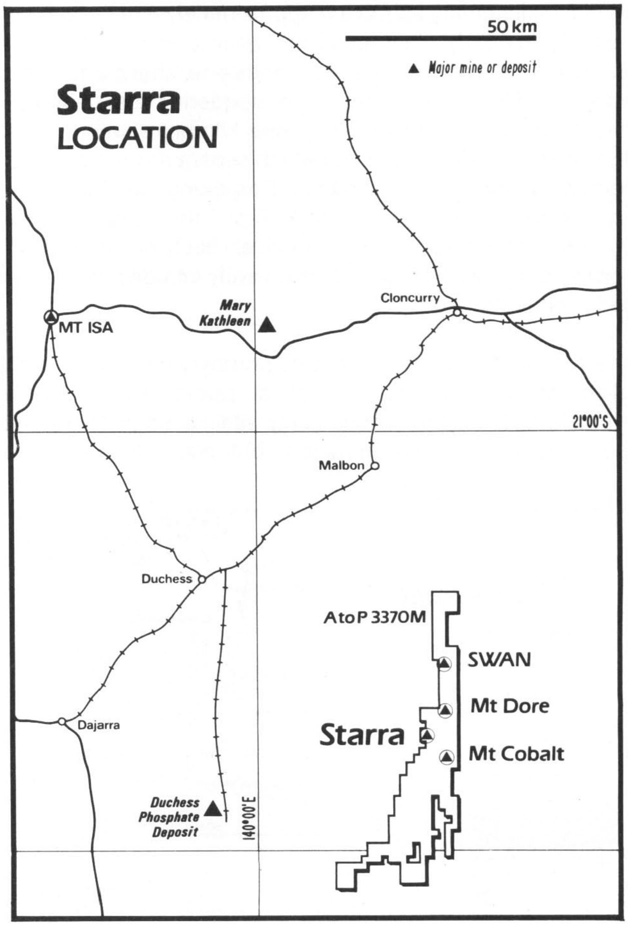

FIGURE 1
Starra location plan.

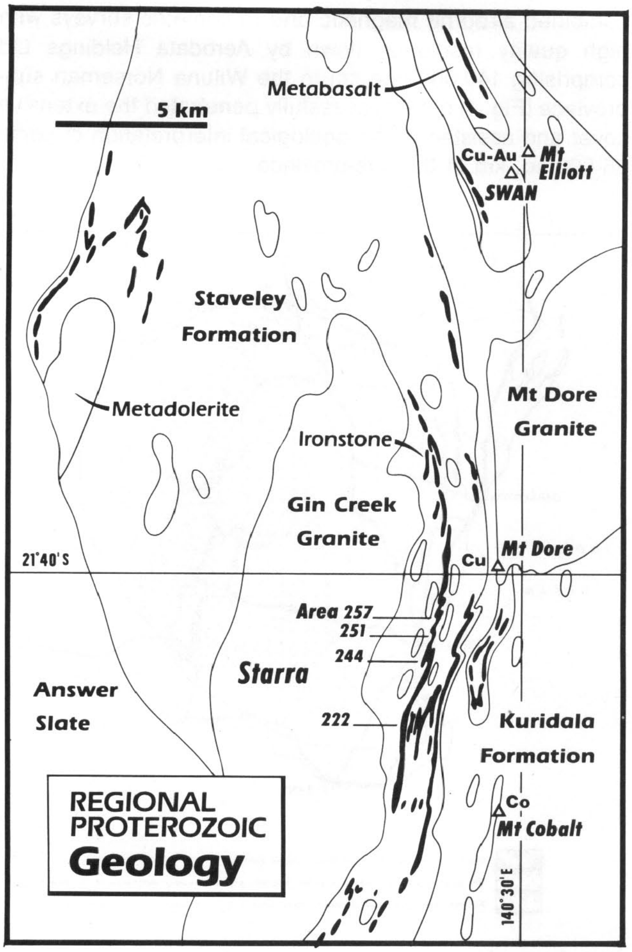

FIGURE 2
Regional geology.

The area is without any evidence of early gold workings and was originally drilled by Newmont and later Amoco as a copper prospect. Minor gold intersections were noted in these programs. As a result of Amoco's earlier success in turning copper to gold prospects, following a sudden rise in gold price, a program of near surface reverse circulation and airtrack drilling was instigated and the area was flown with a close spaced airborne magnetometer survey. The drilling program resulted in the discovery of the Area 251 deposit which is the largest of the mineralised deposits discovered to date.

The discovery that the Area 251 deposit is highly conducting magnetite/chalcopyrite rock led to test EM surveys and these were followed by blanket large loop SIROTEM, detailed ground magnetic coverage and extensive downhole TEM. Test gravity and induced polarisation were also subsequently undertaken.

Early examination of the location of gold bearing zones showed an obvious correlation with aeromagnetic anomalies. Susceptibility measurements on core samples also indicated a correlation between gold and magnetite content. Based on these data, a program of routine susceptibility measurements has been undertaken on all core samples. The results of several thousand such measurements show no statistically significant correlation between susceptibility and gold grade within the mineralised ironstone. Early correlation between mineralised location and aeromagnetic anomalies is due to drill hole locations being biased by the magnetic data. Apparent drill hole correlations from early holes are due to the magnetite and gold being hosted by the same geological horizon. Within this horizon, however, there is no such correlation. Intensive drilling of the strongest aeromagnetic anomalies yielded an abundance of magnetite.

The ground magnetometer survey has covered the length of the known mineralised horizon with 10 × 50 m, and over known mineralisation 5 × 25 m, readings. The major anomalies indicated in these data are not due to the ironstone formation but to the footwall rocks which are a thick sequence of magnetite bearing schists. The magnetic signature of these schists is generally of a much lower spatial frequency than that of the mineralised ironstones. The cause of this is thought to be the greater depth of oxidisation of magnetite to hematite in the schists relative to the ironstones. Good quality outcrop maps of the ironstones were obtained from the airborne data by taking a simple seven point moving average residual. A similar process was applied to the ground data, initially to map the near surface ironstones in a highly structurally complex zone at Area 222. Tests were carried out using a number of filter widths and a two dimensional Gaussian filter with a halfwidth of 25 metres was chosen as suitable for separation of the ironstone and schist responses. This technique was of limited use at Area 222 as the spatial wavelength of the structural events is of the same order or less than the line spacing of the magnetic readings. The filtering technique has been found to be particularly useful, however, in following mineralised non-outcropping ironstones 5 km further north at Area 276. The technique allows the mapping of 50 nT signal against a background of 5000 nT 'noise'.

All the known mineralised zones are surrounded by a halo of high spatial frequency magnetic response, even in areas where the mineralisation occurs at depth. This effect has not been fully investigated and it is not certain whether it is due to a primary magnetite halo, increased structural complexity, a shallower oxidisation depth in mineralised areas or just pure chance.

The presence of massive chalcopyrite at Area 251 caused a rethinking of the geophysical exploration approach for the Starra prospect, away from magnetics to electrical and electromagnetic techniques. Test SIROTEM surveys were carried out over the sulphide mineralisation, and these revealed strong responses in both the moving and fixed transmitter modes. The decay constant for the fixed loop response is approximately 1.3 ms. Downhole SIROTEM revealed a 'classic' response in holes passing through and beside the mineralised body. Decay constants, though somewhat dubious for down hole responses, are generally around 3 ms. The apparent success of the surface TEM in detecting the mineralisation led to the complete coverage of the known mineralised belt with fixed loop SIROTEM. A weak response was detected along the length of the horizon. In contour plan, the results indicated two strong 'bullseye' anomalies and one weaker response. One of the strong anomalies with a decay constant of approximately 1.3 ms lies over and south of the known Area 251 mineralisation. The second, which occurs over a strike length of 1.4 km occurs at Area 276.

The Area 251 anomaly decays to the south, away from the known mineralisation into an area previously undrilled. This was interpreted as being the result of an en-echelon sulphide lens similar to that already known. Two holes were drilled into this anomaly, but neither cut significant sulphides. Downhole tests in these holes showed no significant response in one and only a weak offhole response in footwall rocks in the other.

The response at Area 276 was initially treated with caution due to its large strike length. Downhole results in a hole near the centre of the surface anomaly, however, caused considerable excitement. A strong (5 ms) offhole response was found exactly coinciding with the ironstone horizon. The hole logged had cut 8.9 m of 2 percent copper and 0.5 $gm.t^{-1}$ gold and a hole above had cut a significant gold intersection. The depth of weathering was geologically interpreted to be 8 m below this response, corresponding exactly to the interpreted distance to the EM source. Two holes were drilled based on these data. The first, through the strongest surface EM response turned out to be a 'driller's nightmare'. After enormous expenditures drilling through broken ground only a thin ironstone sequence was cut which contained no sulphides. The second, drilled 50 m vertically below the downhole response also was barren. Downhole EM in this hole gave no significant response.

Three sources of electrical conduction are now recognised in the Starra mineralised horizon. The first, with EM decay response of about 1 ms, is disseminated chalcopyrite in the footwall schists. The second, with a decay of 3 ms is the Area 251 sulphide mineralisation. The third, with a decay of 5 ms, is a zone of clayey, hematite, magnetite rock at Area 276. These have been confirmed using downhole IP/resistivity techniques.

Experience on the Starra project has shown geophysical techniques to be exciting, frustrating, educational and extremely useful in areas you least expect them to be. As such they fit in well among other exploration techniques used on this prospect.

THE USE OF AIRBORNE GEOPHYSICS AND GROUND GRAVITY SURVEYS IN UNDERSTANDING THE GEOLOGY OF THE EASTERN GOLDFIELDS OF WESTERN AUSTRALIA

J. P. Cunneen and Peter Wellman

Introduction

Deep weathering and extensive tertiary and quaternary cover over some 350 000 sq. km of Archaean greenstone and granitic rocks of the Eastern Goldfields province of Western Australia have rendered much of the area inaccessible to direct methods of exploration. This paper shows how combined airborne magnetic and radiometric surveys with high quality resolution flown by Aerodata Holdings Ltd comprising 140 000 line km in the Wiluna Norseman sub-province (Fig. 1) have successfully penetrated the extensive cover and assisted in the geological interpretation of some 25 000 sq. km of the sub-province.

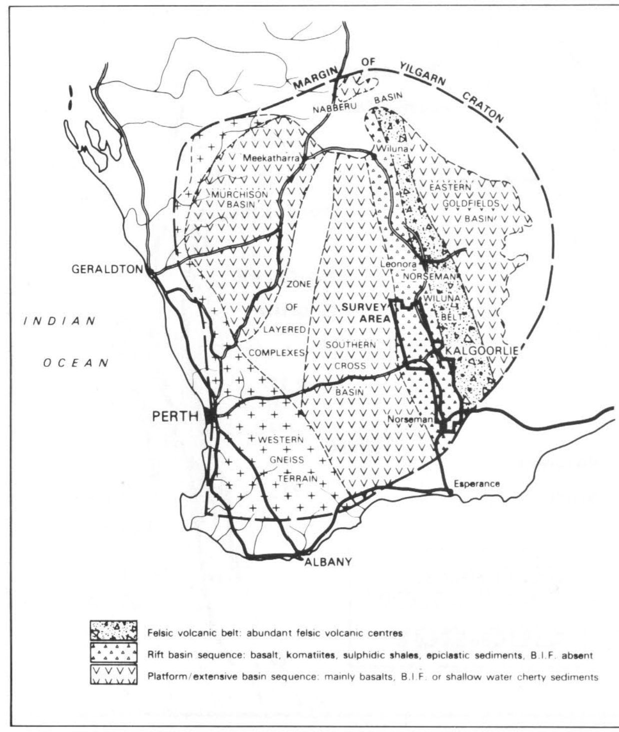

FIGURE 1
A map of the Yilgarn shield showing the survey area.

The magnetics have been particularly useful in showing clearly the close spatial association between gold mineralisation in the greenstone sequences and diapiric granitic intrusions (Colvine 1984; Figs 4 and 5). A model is suggested which relates this close spatial association to the structure of these intrusions.

A detailed horizontal magnetic gradiometer survey over an area of 50 sq. kms augmented the structural control relating to mineralisation (Figs 6(c) and 6(d)).

This area coincides with a detailed gravity survey conducted by the BMR, but the results are not to hand at the time of writing as the field work has just been completed.

The radiometrics delineate high potassium zones associated with mineralisation, interpreted to be a product of sericitic alteration, as well as partly outlining lithological boundaries (Fig. 6(b)).

Specifications

The survey was flown east–west with a line spacing of 200 metres and a sensor height of 60 metres. The magnetometer cycled 3 times per second with a noise envelope during the