Mapping Silicification in Gold Exploration

with Inductive Source Resistivity

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Summary

Silicification or quartz veining is commonly associated with gold mineralization. Resistivity surveying is a geophysical technique that has been used to map zones of high resistivity associated with silicification. Associated IP measurements may also be useful to locate sulphide mineralization often associated with gold.

Geophysical measurements of ground resistivity have usually been confined to pure galvanic (electric bipole source and receiver) or pure inductive (loop source and induction coil or magnetometer receiver) measurements. It is possible to use combinations of electric bipole and loop sources/receivers, as is done for example in MMR surveys (Edwards et al.,1978). This discussion considers the use of the UTEM time domain system, which has an ungrounded loop source and both magnetic and electric field sensors, to collect inductive source resistivity (ISR) and inductive source IP (IIP) data. The UTEM system is described in West et al.,1984.

In a test in New South Wales, Australia, a UTEM ISR survey mapped in detail the two known zones of silicification at a gold prospect. The ISR highs corresponded exactly with the drilled location of silicification, and the data were very similar to existing gradient array apparent resistivity data. Anomalies were not observed in either the UTEM IIP or the gradient array IP data. This is not all together surprising, since no fresh sulphides were encountered in the drilling. Generally, however, as part of an exploration program, combined collection of UTEM E and H field data can identify, in one survey, both resistive and conductive features, contacts and disseminated sulphides, if present.

Gold as a geophysical target

Gold mineralization as a target has attracted considerable exploration interest. Economic deposits of gold typically contain very small volume percentages, usually less than 0.001% of gold itself. Geophysical exploration techniques using potential fields primarily map bulk physical properties. As a result, when geophysics is applied in the search for gold, it has almost exclusively focussed on exploration for either favourable structures/ host-rocks, or on exploration for any associated minerals which are present in a much larger volume percent. For example, favourable structures may include features such as contacts between metasedimentary and metavolcanic rocks. Minerals commonly associated with gold are sulphides and quartz.

While some effort has been expended on direct methods of quartz detection using piezoelectric effects (seismo-electric effects), the technique has yet to be proven viable. As a result, a frequently used geophysical technique in the search for Archean gold has been resistivity/IP surveying, which may detect both the resistive zones associated with silicification and the polarization effects caused by disseminated sulphides. Another technique commonly used is a combination of VLF EM and magnetic surveying which is inexpensive and useful for outlining contacts. Low frequency or time domain EM surveys are also undertaken to search for more conductive targets indicative of massive sulphides that are sometimes associated with gold.

Based on the work of Macnae (1981), several tests of inductive source resistivity (ISR) and inductive induced polarization (IIP) techniques have been performed to evaluate their application in detecting silicification and sulphide mineralization. The test reported here is one for which geological and gradient array resistivity data are available for comparison with the UTEM E field data.

The test site

The test site is a gold prospect in central New South Wales, Australia. The locations of 33 drillholes in an area approximately 300m by 200m in size are presented in Figure 1. The drilling has located a number of zones of silicification which are shown as zones on the location map. The silicification appears in narrow zones as indicated in the drill logs presented later in Figures 5,6 and 7. Due to the commercial sensitivity of the project, no grades of gold mineralization associated with this silicification have been released to the author.

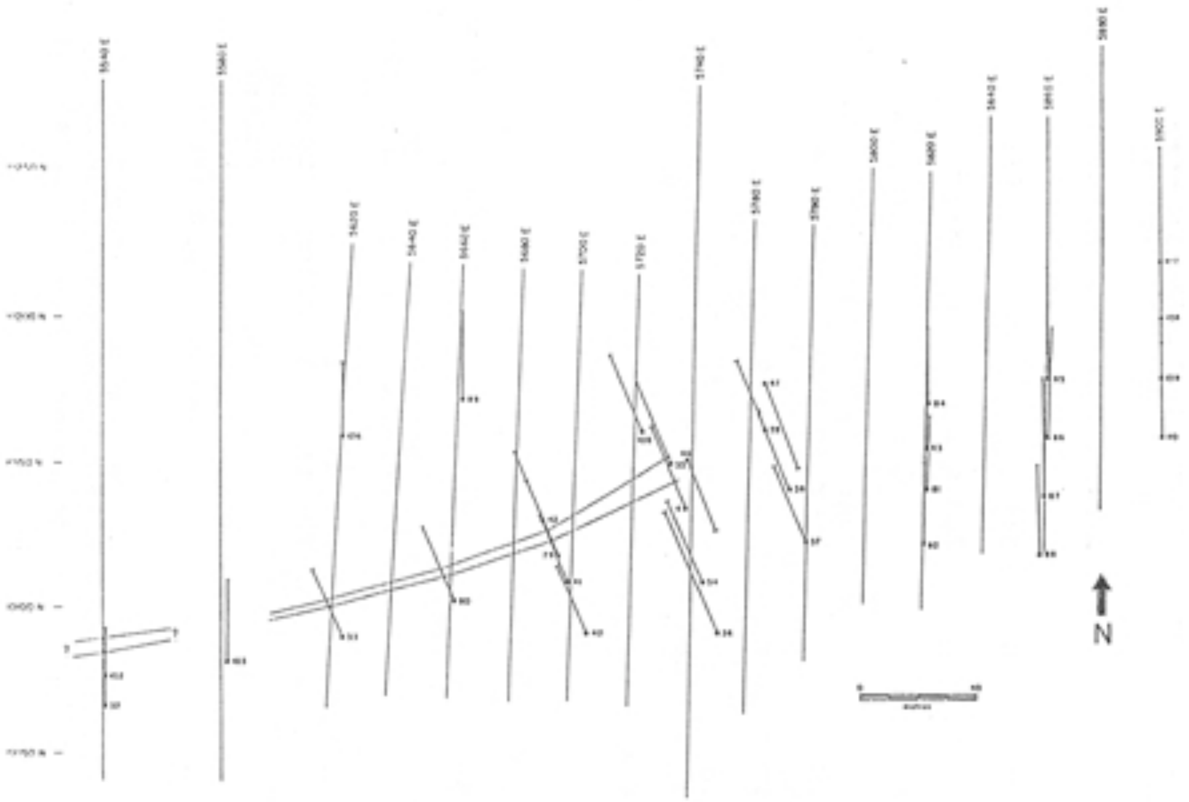

Figure 1: Location of the test site in central New South Wales showing the locations of the drill holes and the main zones of silicification

In this area, the near surface is fairly heavily weathered, with about 20m to 30m of conductive clays associated with in-situ weathering. Some limited transported overburden patches are also present.

UTEM e-fields and inductive resistivity

The way in which the UTEM system induces a constant current flow in the ground is simple. The transmitter waveform can conceptually be regarded as a set of ramps of constant slope and alternate polarity .... a sawtooth waveform[1]. When the current in the transmitter is ramping up, the current has a constant time derivative dI/dt.

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[1] IIn practice the actual waveform is optimized for maximum signal-to-noise ratio through the use of prewhitening and deconvolution techniques as described in Macnae et al (1984).

This constant time derivative creates a primary magnetic field H which also has a constant time derivative dH/dt. In the ground, an electric field E is induced according to Faraday"s law such that the circulation of E is equal to the rate of change of magnetic flux:

$$\mathrm{curl}E = - dB/dt \qquad [1]$$

where $B = \mu H$.

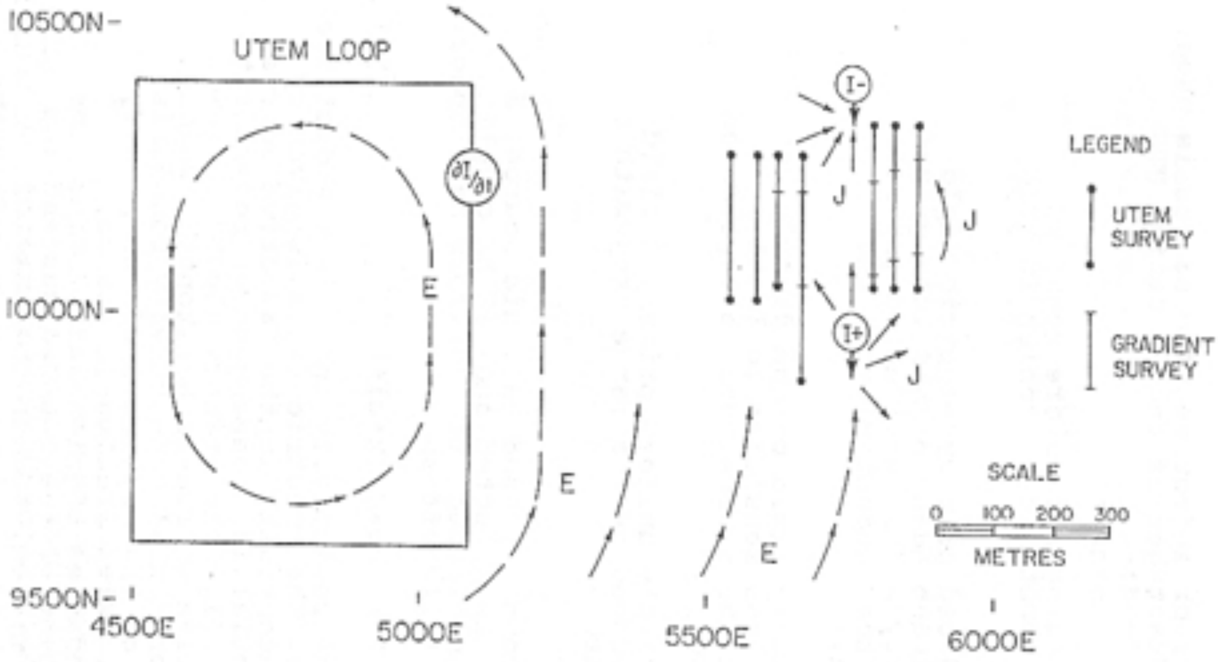

Figure 2: Layout of the gradient array galvanic and UTEM Y field inductive transmitters. The galvanic source primary field id shown by the current vectors J and the inductive source by the electric field vectors E.

This primary electric field is a function only of location and independent of time or conductivity structure. Figure 2 shows the primary E field circling the transmitter loop. For a certain time after the ramp has switched polarity, EM secondary field transients oppose the build-up of a constant current flow. The time taken for these transients to decay is dependent on the conductivity of the ground; the greater the conductivity the longer the transient decay.

To detect resistivity contrasts with the electric field, an ISR or standard resistivity (i.e. galvanic source - Gradient array) survey is set up so there will be a primary E field cutting across strike. The advantages of the inductive UTEM source compared to a galvanic source are fourfold:

1) no grounding points are required. These are sometimes a problem in arid areas;
2) the induced primary electric field level is independent of absolute ground conductivity and is unaffected (at late times) by the conductivity of the overburden;
3) the primary field of the distributed source is less sensitive to local effects at the source than is a grounded source; and
4) a relatively uniform primary E field can be produced over a large area with a single source.

With the more commonly used galvanic source, a fixed current I is injected and, if EM coupling effects can be neglected, the (uniform half-space) potential then falls off as

$$V = rho*I/(2*pi*r) \qquad [2]$$

where rho is the resistivity and r is the distance from the source. The electric field is given by E = -dV/dr. In contrast, in the inductive source case, the potential is independent of resistivity rho by equation [1]. The primary electric field from the inductive source is horizontal, which implies that horizontal conductivity boundaries have no effect on the amplitude of the primary electric field. With a galvanic source, horizontal boundaries significantly affect the vertical component of the induced current and electric field system, and in the case of conductive overburden, significantly reduce the electric field beneath the overburden. The intermediate distance primary field of the inductive source falls off as I/r which is much slower than that from a grounded electrode which falls off as $1/r^2$. Thus it is possible to survey much larger areas from a single source setup using inductive sources.

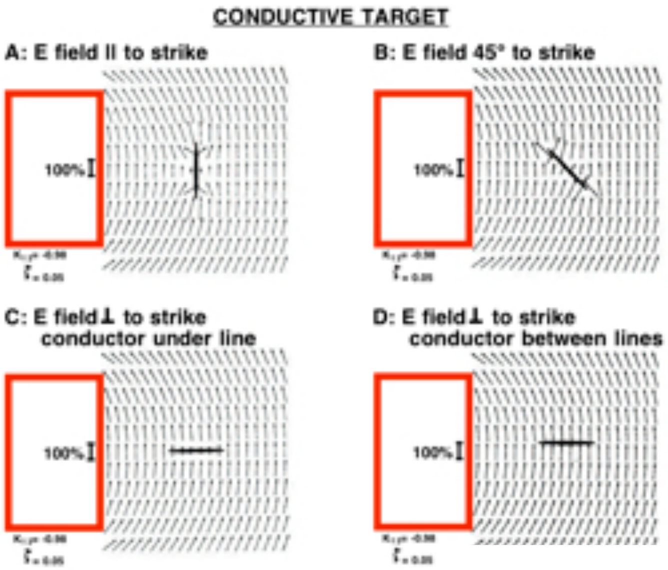

Figure 3: ISR response over a thin conductive target as a function of strike angle. The vectors represent the amplitude of the late time E field normalized to the calculated. primary field.

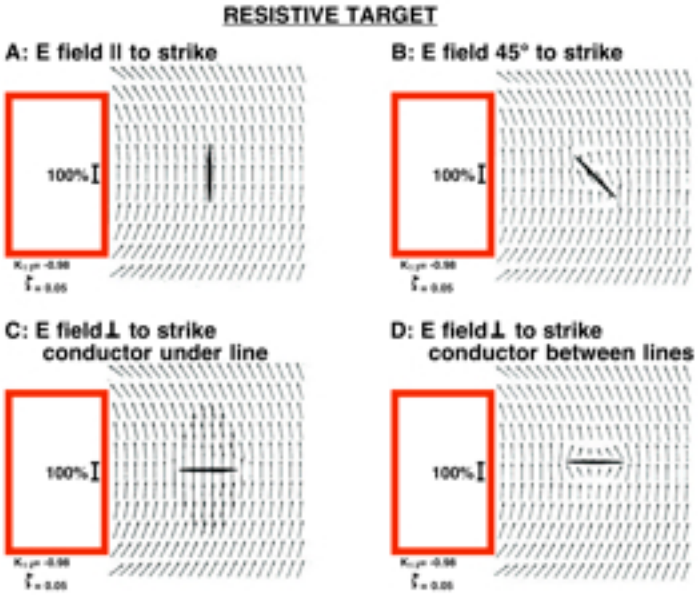

Figure 4: ISR response over thin resistive target as a function of strike. Note the maximum response when the primary field cuts across the target as opposed to a conductive target which is maximized when the field is along strike.

The expected size of a resistivity anomaly is controlled both by geometry and resistivity structure. Figures 3 and 4 show two examples from Macnae (1981) relating to the detection of thin bodies of finite strike length. The vectors plotted show the relative amplitude of the ISR response from an inductive loop source as shown. It is evident that in exploration for conductive bodies, the regional current should be induced to flow parallel to strike, whereas for resistive bodies, a current system perpendicular to strike is optimum. If both types of target are of interest, arranging the transmitter so that the regional current system is at 45 degrees to strike is an alternative that has not yet been tested.

UTEM Survey Field Data

Seven lines of field data were collected with the UTEM system in May, 1988. Since this test was designed purely to look for resistive features, the transmitter was laid out along strike so that the primary electric field would be across strike in the area of interest. Stations spacings used were 10 metres as was the case in the gradient array data. Figures 5, 6 and 7 show comparisons of the late time (12.8 msec delay) E field data (ISR) measured along the line (Ex) with the "gradient array resistivity and drill hole data. In all cases, clear, ISR highs with narrow widths are located above drilled silicification. Figure 8 presents a contour map of all the observed ISR data. Note the excellent correlation of the ISR determined resistivity highs with the known silicification.

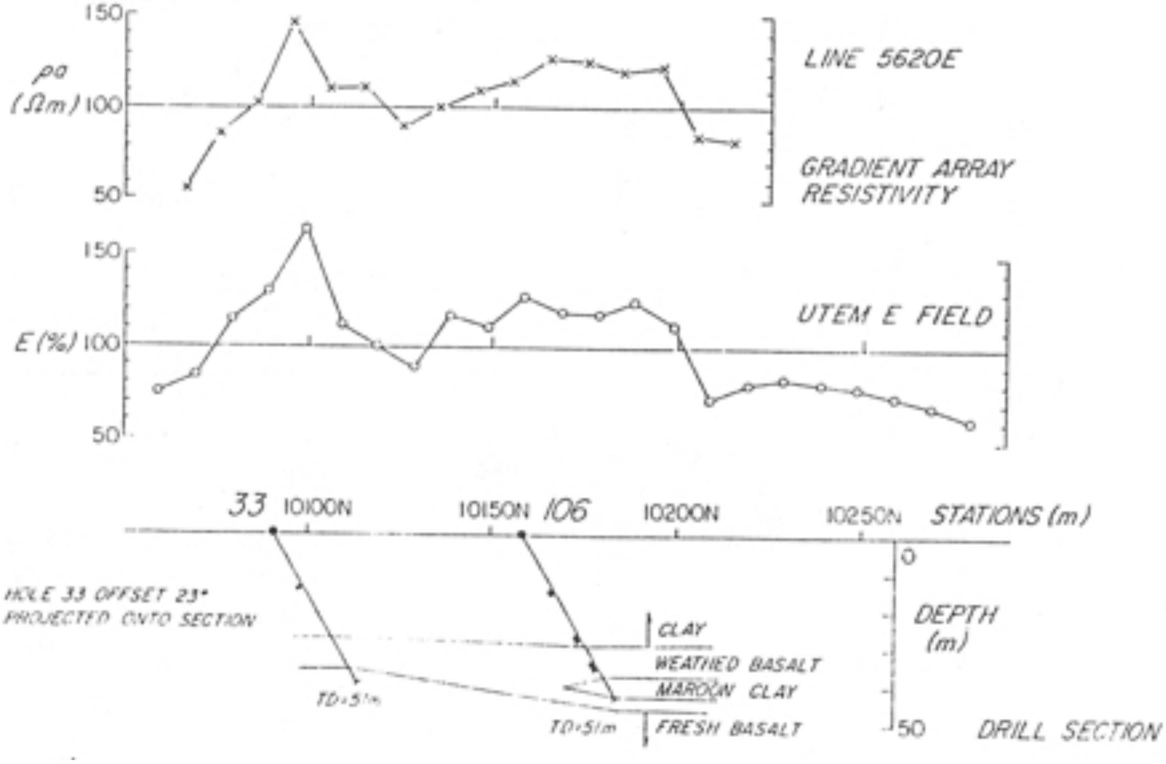

Figure 5: Comparison of Gradient array apparent resitivity, UTEM ISR data and drill results on line 5620E

On line 5580E (Figure 7), where no gradient array data was collected, there is an ISR resistivity high located directly along strike from silicification on lines 5540 and 5620E. The log of DDH 103 however did not contain any evidence of silicification. Without more drill data, it is not possible to say whether the absence of silicification is very local or has a larger extent. The ISR anomaly on this line is quite clear, and of similar amplitude to that on adjacent lines indicating that on average the physical properties are not very different. The geophysical interpretation would thus be that the absence of silicification is local to that particular drillhole.

On line 5620E, (Figure 5), DDH 33 has detected a narrow zone of silicification beneath about station 10100N, and DDH

106 has outlined a number of narrow zones from stations 10160N to 10180N. Both the gradient array resistivity and the ISR E field data show a narrow peak around 10100N, and a much wider peak over the multiple zones further north.

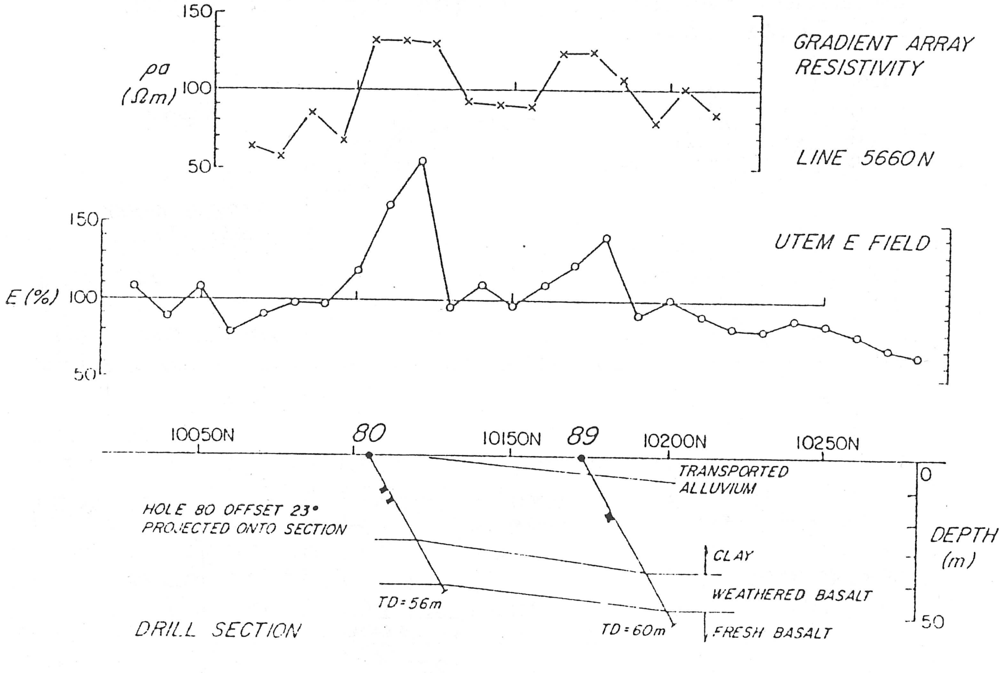

Figure 6: Comparison of Gradient array and ISR data with drill results on line 5660E.

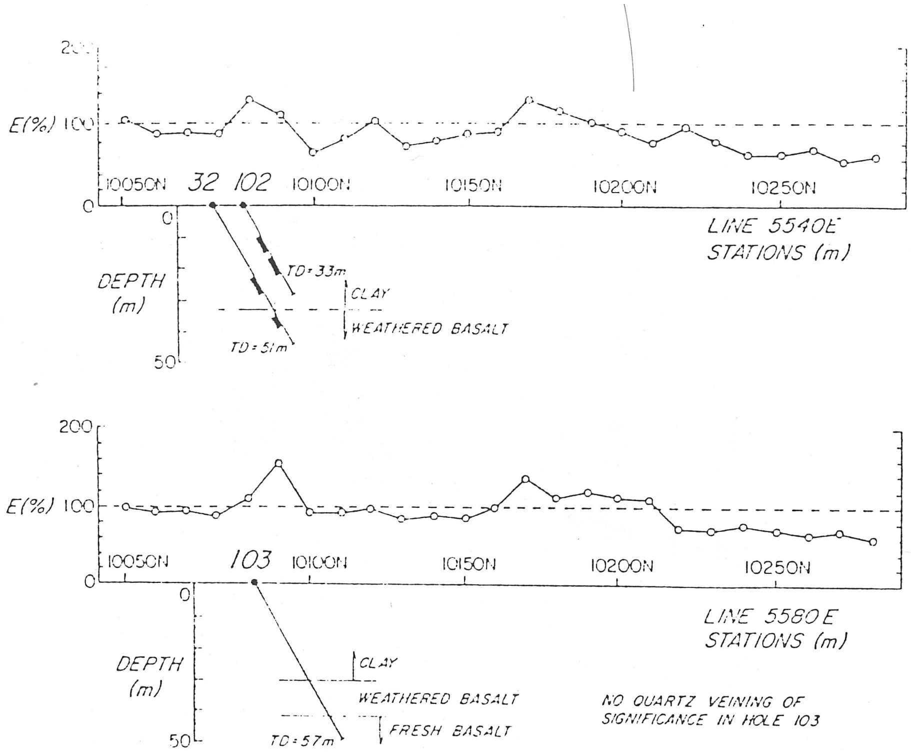

Figure 7: ISR data and drill logs on lines 5540E and 5580E

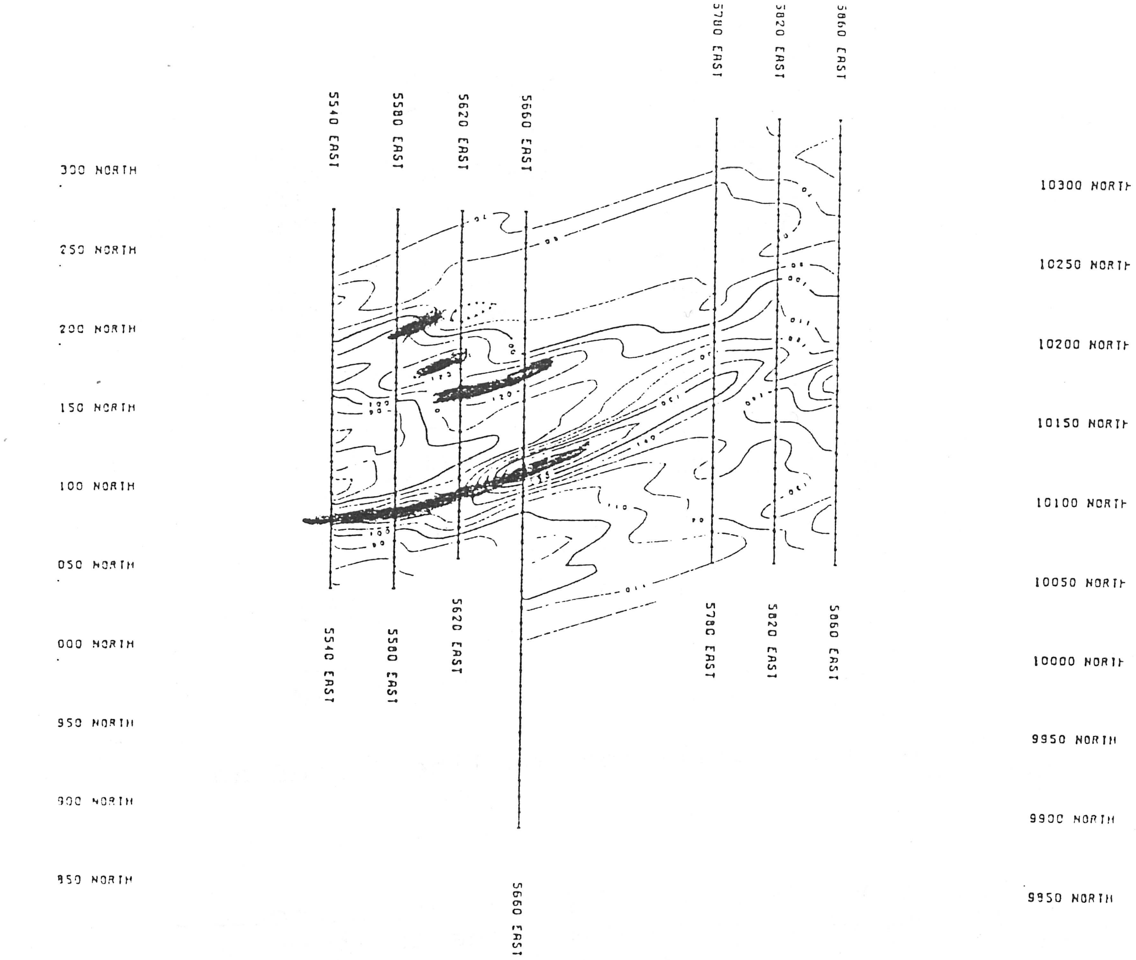

Figure 8: ISR Contours over the survey grid. The zones of silicification are shaded.

Induced Polarization Effects

For the NSW test case here, both the gradient array data and the IIP data exhibited no detectable polarization anomalies associated with the silicification. No fresh sulphides were mapped in the drill logs.

Conclusion

Electric field measurements from an inductive source are a viable alternative to conventional resistivity/IP surveys in gold exploration. The primary electric field at depth in the ground is unaffected by a covering layer of conductive weathering or overburden, and the technique is well suited to this condition. As part of a general exploration strategy, a combined UTEM E and H field survey provides a quick, effective and inexpensive alternative to conventional methods.

References

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