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Case Study: Dighem survey for non-magnetic dyke detection; Dorstfontein colliery, Total Coal RSA

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ABSTRACT

A Dighem airborne geophysical survey (simultaneous acquisition of airborne magnetic and electromagnetic data) was carried out for Total Coal South Africa from September 14 to October 23, 2007. Three blocks in the Secunda area were flown, namely: Dorstfontein, Boschmanskop-Tumelo and Forzando West. This paper deals with the Dorstfontein colliery survey only. The Dorstfontein mining area is located immediately east of the town of Kriel in Mpumalanga, South Africa. The purpose of the survey was to detect both magnetic and non-magnetic dykes. The data quality from the Dighem survey is very good and much improved on previous similar surveys in the 1990s and in 2000. This is due to improvements in technology, especially electronics. The Dighem survey successfully delineated known magnetic and non-magnetic dykes in the Dorstfontein area, as well as probable and possible dykes. Some 60% of the known and probable and possible dykes were detected by the magnetic method and 40% of the probable and possible detected dykes were non-magnetic. Using two flight directions at right angles to each other proved to be important, since if only one flight direction was used, some of the dykes may not have been detected.

Key words: Dighem, dykes, non-magnetic dykes, electromagnetic, airborne geophysical survey, Total Coal, Dorstfontein Colliery.

INTRODUCTION

The majority of the economic coal in South Africa was deposited in Permo-Carboniferous times. Later, in Jurassic times the formations were invaded by dolerite dykes and sills. In many cases the sill intrusions are concordant with the bedding and frequently migrate between stratigraphic levels. Where this occurs the sills often adopt a dyke-like vertical geometry. Where the sill moves from above to below a seam the coal horizon is up thrown by the thickness of the sill (Saunderson and du Plessis, 2000), Figure 1.

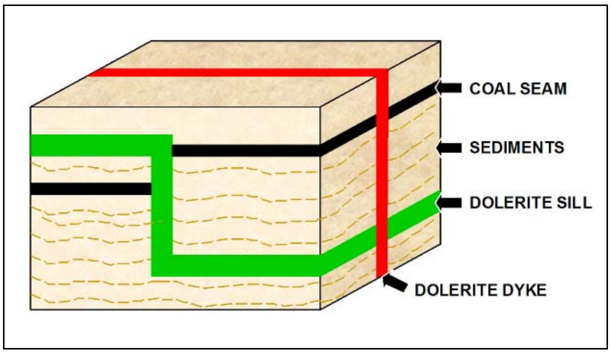

Figure 1. Geological model illustrating the coal seam and intruded dyke and sill.

If the sills are in close proximity to a mineable seam large amounts of potentially economic coal can be destroyed by burning or devolatization. Therefore dolerite sills can be a major contributor in defining the economically mineable reserves. On the other hand dolerite dykes are usually relatively straight linear features which are vertical or near vertical. When these traverse the mineable reserve blocks they present a physical obstacle to mining. The prediction of the size, extent and frequency is important so their effect can be mitigated. Provided accurate knowledge is available the design of the mine can be adjusted to mine panels between the dykes and to reduce the number of entries which must be blasted through the dykes (Saunderson and Du Plessis, 2001).

Holz (1992), in the Kriel area, found that there was poor correlation between actual dykes and field magnetometer surveys because 49% of the dykes have a low magnetic response or none at all (hence the description non-magnetic dykes).

The Dighem system has been proven to successfully detect non-magnetic dykes since 1997. (Du Plessis, 1997; Saunderson and Du Plessis, 2001);

A helicopter Dighem airborne geophysical survey (magnetic and electromagnetic (EM) techniques) was carried out for Total Coal South Africa from September 14 to October 23, 2007. Three blocks in the Secunda area were flown namely: Dorstfontein, Boschmanskop Tumelo and Forzando West. The total line kilometres flown were 7598 km. This paper deals with the Dorstfontein survey only. A locality plan is shown in Figure 2. The purpose of the survey was to detect both magnetic and non-magnetic dykes.

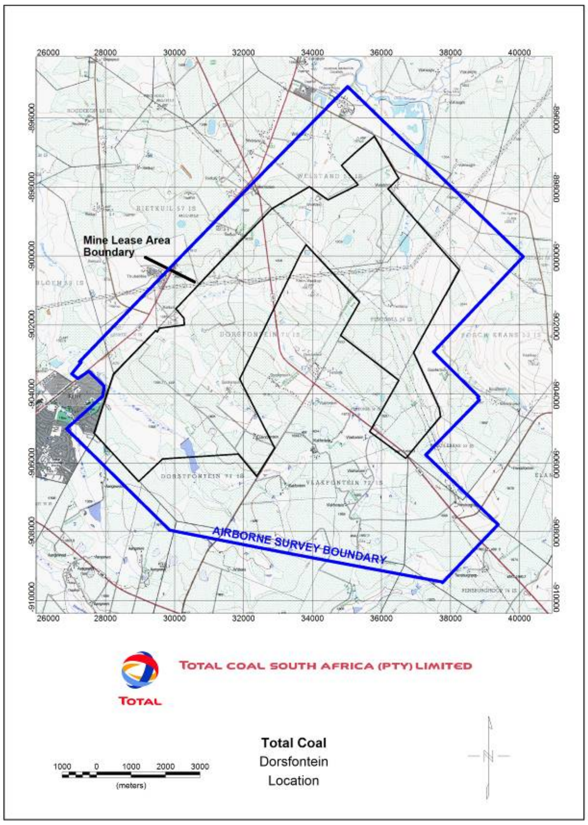

Figure 2. Locality plan of the Dorstfontein Colliery Dighem survey. The town close the left hand corner of the picture is Kriel, in Mpumulanga, South Africa.

The Dighem survey successfully delineated both magnetic and non-magnetic probable and possible dykes in the Dorstfontein area.

Using two flight directions at right angles to each other proved to be important, since if only one flight direction was used, some of the dykes may not have been detected.

METHOD AND RESULTS

The Dighem EM system is operated by Fugro Airborne surveys and is a multi-coil, multi-frequency electromagnetic system, supplemented by a high sensitivity cesium magnetometer. The information from these sensors was processed to produce images that display the magnetic and conductive properties of the survey areas. Electromagnetic data was recorded with five frequencies and co-axial and coplanar transmitter and receiver pairs. The electromagnetic data detects the nonmagnetic dykes. Total Field magnetic data was also required. The Total Field magnetic data is useful for detecting magnetically susceptible intrusives (dykes), and to map out magnetically susceptible sills. Most of the magnetic dykes were also detected using EM. The magnetic data is useful for confirming that the EM data is actually detecting known dykes and also to provide confidence in the interpretation of probable and possible dykes. By comparing the magnetic and EM data, it was also possible to unequivocally identify pre-Karoo magnetic dykes.

The area was surveyed with a 50 m line spacing and in two line directions, NE-SW (45°) and NW-SE (135°). The reason is that past experience has shown that, because the dykes trend in all directions, one survey line direction does not detect all the dykes. This is especially so if the dykes trend parallel or sub-parallel to the survey line direction.

The results from two line directions, illustrating that a single line direction would not have detected the dykes for the 7200 Hz resistivity enhanced images are shown in Figure 3. Generally, the best results are obtained from the 7200 Hz coplanar resistivity, mainly due to the better signal to noise ratio of the 7200 Hz coplanar channel. The reason for this is unknown.

For geophysical purists, the 50m line spacing may seem to be an over-kill and adding unnecessary costs. However, using a 50m line spacing in two flight directions have become standard practise for a number of reasons.

Firstly, the dykes produce small anomalies, not detectable on single profiles, often within the noise level of the system (10-40ppm). By applying standard high pass filters (automatic gain control and second vertical derivative filters) and gridding of the data, the ‘noise’ becomes coherent, and the dykes become visible. In the past, wider line spacing than 50m produced very noisy results, making it difficult to impossible to unequivocally distinguish dyke anomalies in the data.

Secondly, whilst the raw field data provides an indication of whether the EM is detecting the non-magnetic dykes, the filtering produces best results on final levelled EM data.

Thirdly, following from this, the final processed and drift corrected EM data are received from Fugro long after the completion of the survey. Should it then become apparent that the line spacing used was too large to detect dykes, it is not possible to remobilise to redo the survey or add in additional lines. Remobilising will be impossible due to the fact that the Dighem system is not readily available in Southern Africa and therefore too costly to remobilise.

For these reasons, it has been decided not to gamble with wider line spacings, but rather to collect optimal high resolution quality data, that will surely detect and show the non-magnetic dykes.

Cultural metallic features such as fences produce similar anomalies to that of the dykes. A large portion of the interpretation effort goes into discriminating cultural versus dyke EM responses. The best way of discriminating between cultural and dyke response is to use the 1:50 000 topographic sheets and field checking of anomalies (Figure 4).

Lineaments were identified from the magnetic (Figure 5) and Dighem resistivity images (Figure 6) and classified as probable and possible dykes as well as unclassified lineaments (Figure 7). Some of the unclassified lineaments may in fact be dykes, either very thin or with a felsic rather than mafic composition, and thus not unequivocally detected by either the magnetic or the resistivity method. Felsic dykes are not magnetically susceptible and do not weather to a conductive clay. Thus neither the magnetic nor the resistivity methods readily detect these dykes in this geological environment.

Some 60% of the interpreted dykes were detected by the magnetic method and 40% of the interpreted dykes are non-magnetic (Figure 8).

CONCLUSIONS

The Dighem survey successfully delineated both magnetic and non-magnetic probable and possible dykes in the Dorstfontein area. Some 60% of the interpreted dykes were detected by the magnetic method and 40% of the interpreted dykes are non-magnetic.

Using two flight directions at right angles to each other proved to be important, since if only one flight direction was used, some of the dykes may not have been detected.

ACKNOWLEDGMENTS

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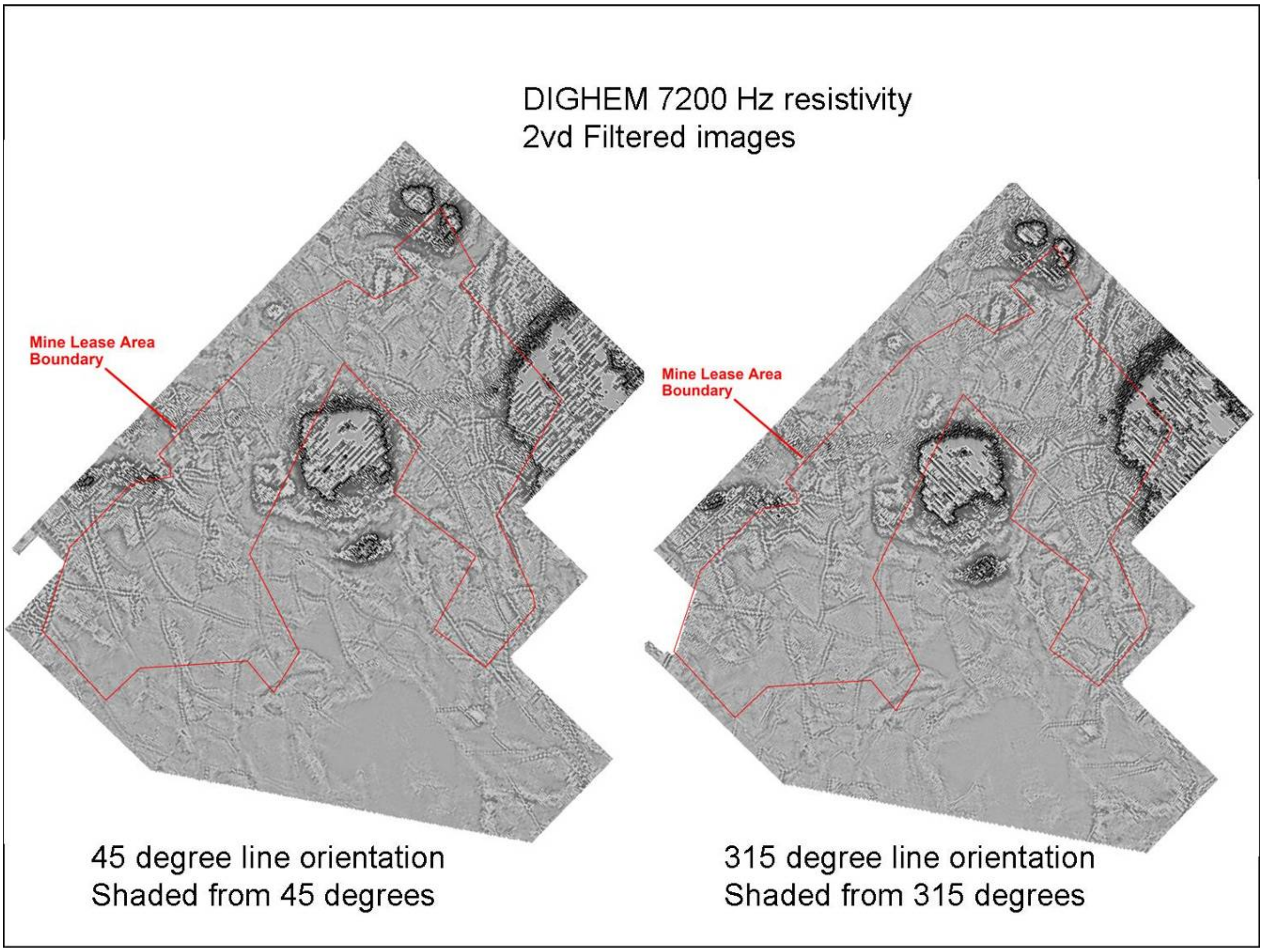

Figure 3. Two survey line directions for the 7200 Hz resistivity enhanced images, illustrating that a single line survey direction would not have detected all the dykes.

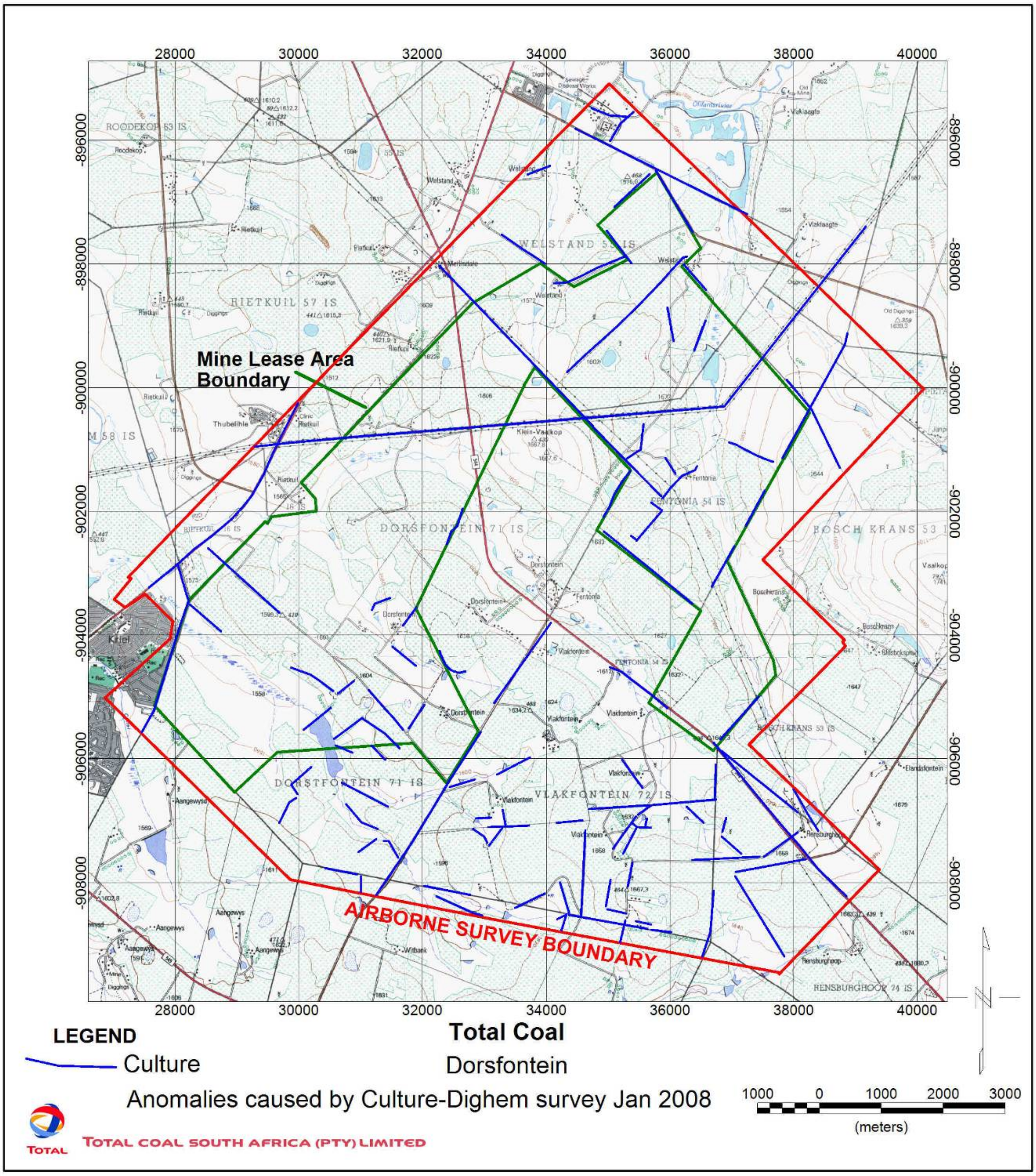

Figure 4. EM anomalies due to culture shown on the 1:5000 topographical map.

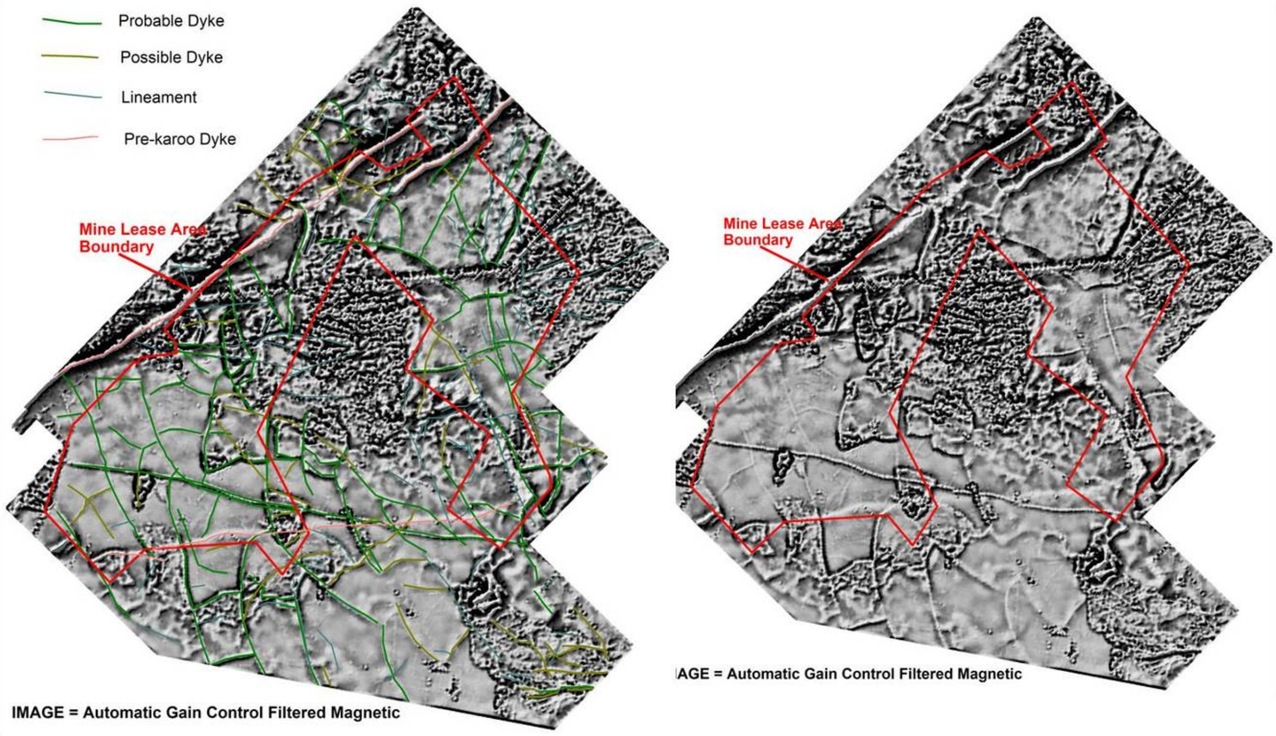

Figure 5. Identified probable and possible dykes from the Dighem information and unclassified lineaments on the automatic gain control filtered magnetic image. The high frequency response over extensive areas is caused by basement rocks.

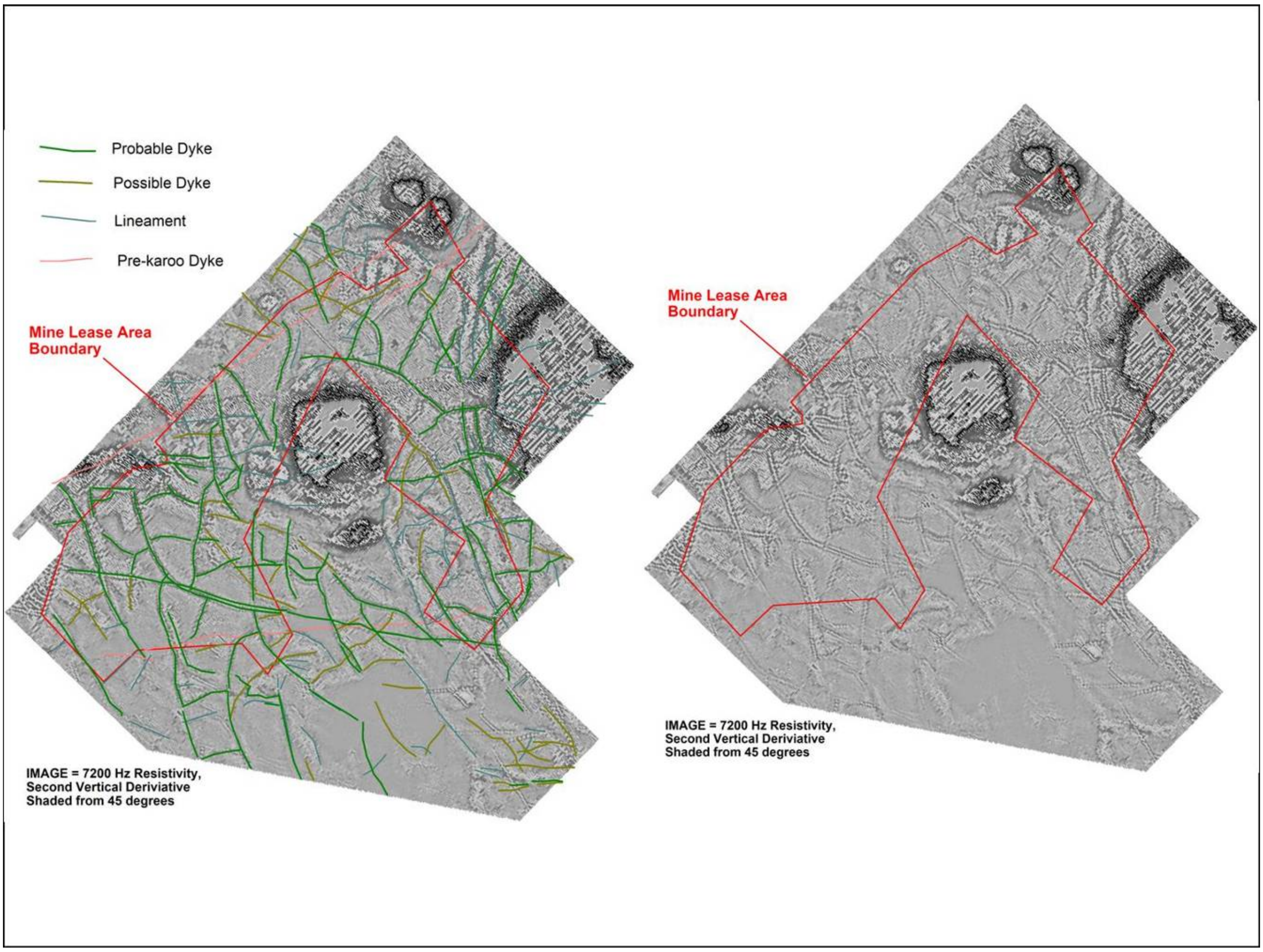

Figure 6. Identified probable and possible dykes from the Dighem information, as well as unclassified lineaments shown on the 7200 Hz Dighem resistivity image (one line direction only, 45 degrees).

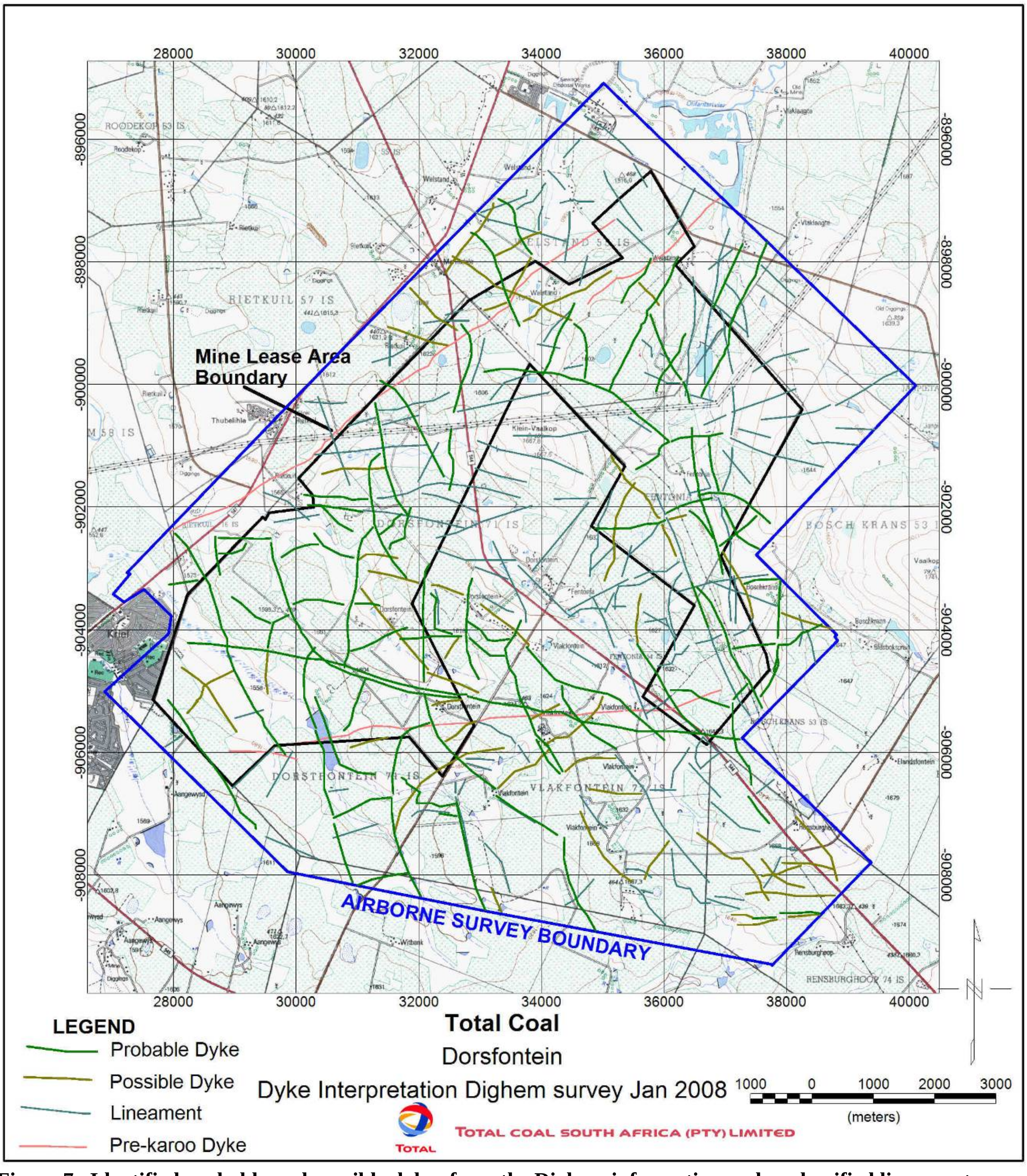

Figure 7. Identified probable and possible dykes from the Dighem information and unclassified lineaments.

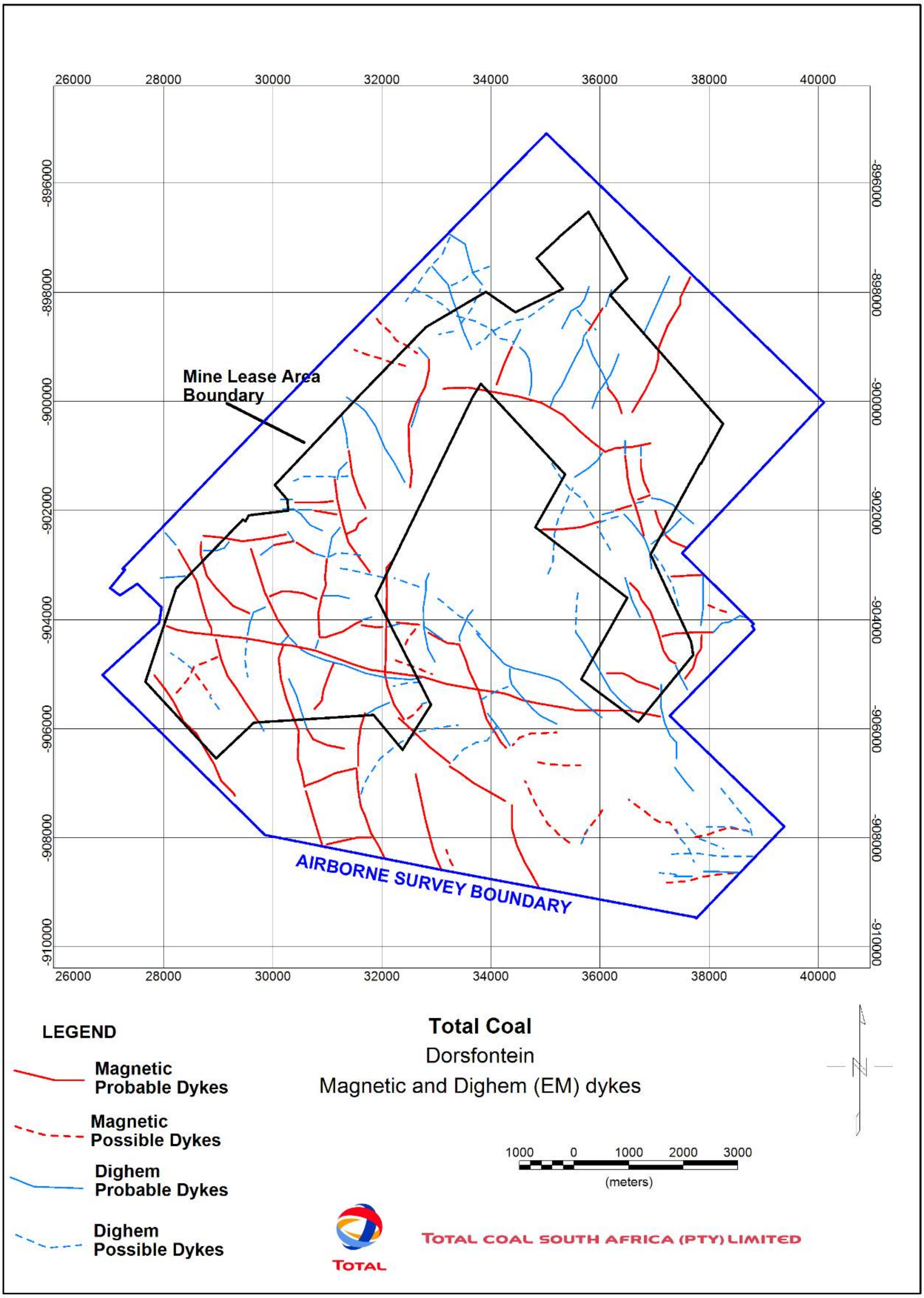

Figure 8. Dykes detected by the magnetic method versus dykes detected by the EM method from the Dighem survey. The data shows that in this area, approximately 60% of the dykes could be detected by magnetics and 40% are non-magnetic (detected by EM).