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Summary of trials of an integrated gold exploration system at Chakari, Zimbabwe.

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ABSTRACT

An integrated system of exploration for gold-sulphide mineralisation in shear zones was tested in the Chakari area of Zimbabwe. This integrated system was developed in Ghana and uses the shear zone as the exploration target. This is located by interpretation of aerial photography of geological settings favourable for gold mineralisation. The shear zone is located on the ground by vapour geochemistry traverses across its strike and sulphide-rich portions are determined from detection of high CO_2 values. These sites are tested for gold mineralisation by processing the overlying residual soils using a soil loaming technique, improved by the use of large soil samples for sieving and panning, the concentrate obtained being passed over a spiral concentrator to extract the gold. The gold particles are counted on a gridded pan.

The shear zones at Chakari have no topographic expression but are readily identified on aerial photographs as they form distinct lineaments. In an orientation study high CO_2 values were obtained over the Arlandzer shear zone and a small footwall shear zone. These high CO_2 values are associated with high gold particle counts, which form a zone of elevated values extending for about 60m on either side of the peak gold particle counts directly over the mineralised shear zone. The footwall shear zone is associated with high radon and thoron values, probably indicating the presence of water in it. High CO_2 values near the old Bonzo 2 shaft are related to sulphides only, the gold particle counts being low.

In a gold exploration exercise over a ploughed field at Chadshunt farm, a shear zone was traced in a south south-westerly direction beneath the field by following its CO_2 signature until it died away. The presence of gold mineralisation was established by soil loaming. This exploration exercise was performed with minimal interruption to farm work.

The integrated exploration system was shown to work in the semi-arid conditions at Chakari. The uses of aerial photographic interpretation and vapour geochemistry will be of more interest to exploration companies than the soil loaming since they can afford to use the geochemical laboratories in Zimbabwe. The soil loaming will be of more interest to the prospectors and small-scale miners in the exploration of their claims. Prospectors and small-scale miners form an important grouping in the rural economy in Zimbabwe and improvements in their expertise will also benefit the exploration companies who often develop mineral occurrences first found by prospectors.

1.0 INTRODUCTION

The purpose of testing the integrated system of gold exploration in Zimbabwe was to see if it would work in the sem-arid, single wet season, low-bush grasslands of central Africa. The evaluation fieldwork was carried out in the Chakari area during July and August 1987 at the kind invitation of Falcon Mines Ltd.. The Chakari area around Dalny mine was very suitable for the tests, as gold-sulphide shear-zone- controlled mineralisation is present, somewhat similar to that at Ashanti mine in Ghana where the writers had previously worked (Crow and Laffoley 1988).

2.0 INTEGRATED GOLD EXPLORATION

The typical method of exploring for high-grade gold-sulphide mineralisation in shear zones in Zimbabwe is to sample soils on widely spaced (50-100m) grids. This method works because elevated gold values in shallow soil samples extend for several ten's of metres on either side of the anomalous linear zone overlying the gold mineralisation (Viewing 1987). This wide dispersion of gold in residual soils is likely related to the prolonged period of weathering and topographic planation which has formed the ancient landsurfaces of Zimbabwe (Lister 1979). This type of gold dispersion does not occur so markedly when the gold deposit is low-grade, or with high-grade deposits when the landsurface is youthful. In such circumstances the initial exploration grids have to be very much smaller and very many more samples are generated for analysis.

Early in 1987 the writers tested simple gold exploration methods over narrow zones of gold-sulphide mineralisation in youthful soil profiles at the Ashanti mine, Ghana (Crow and Laffoley, 1988). From the lessons learned in this orientation study an integrated gold exploration system was proposed. The system uses simple and relatively inexpensive apparatus, and laboratory facilities are not required, at least in the early stages of exploration.

In this proposed system of exploration for gold-sulphide mineralisation, instead of sampling grids to find elevated gold values in shallow soil samples exploration is focussed on finding promising sections of sulphide mineralisation in the host shear zones. Aerial photographs are examined for shear zone lineaments, which are located on the ground by making vapour geochemistry traverses across their strike. The sulphide-mineralised portions are precisely located by high values of carbon dioxide and low values of oxygen in the soil gases. Shallow soil samples are then loamed to see if gold particles are present in the soils. The source of the gold mineralisation lies at depth beneath the residual soils with the highest particle counts. When the soil cover is of transported origin, the samples to be processed should be taken from beneath the cover

3.0 INTEGRATED GOLD EXPLORATION SYSTEM METHODS

3.1 Aerial photographic interpretation

Stereoscopic examination of aerial photographs of suspected shear zone-hosted gold mineralisation, enables shear zone lineaments to be discriminated from other photolineaments such as lithological boundaries, joint zones and faults. Having

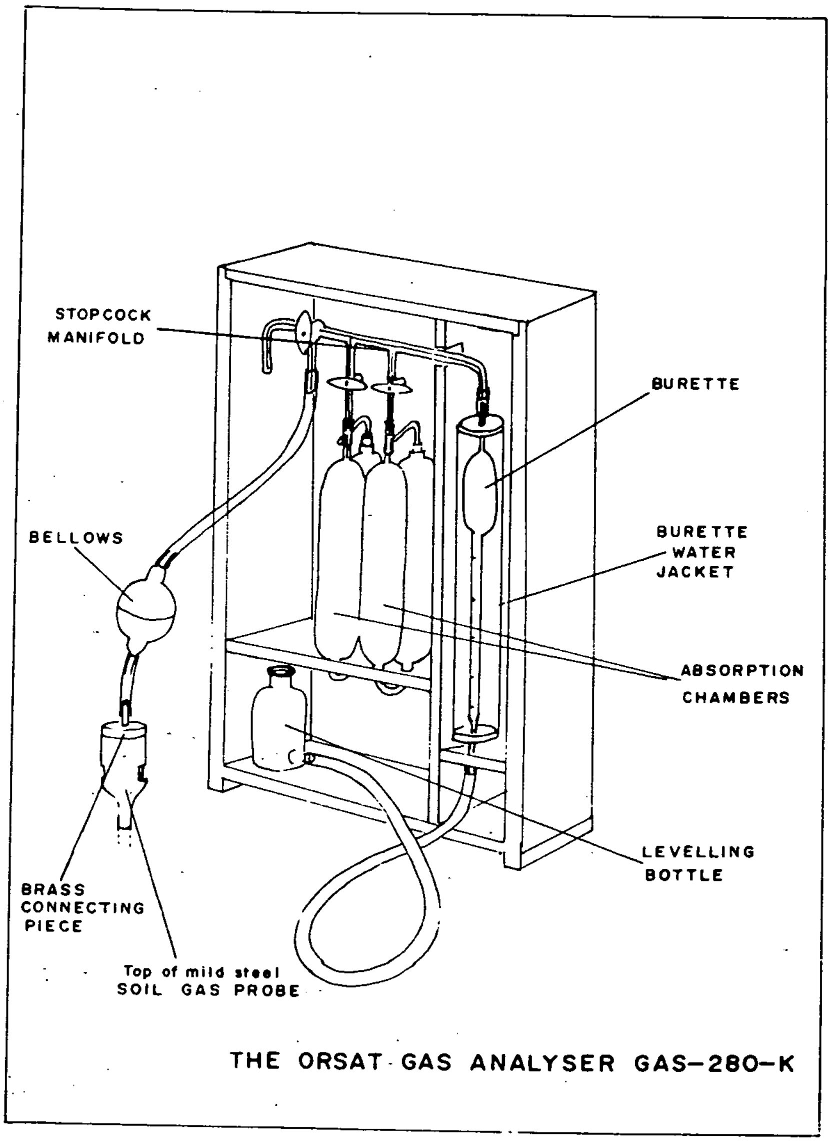

Fig. 1 The Orsat Gas Analyser.

located a shear zone in a promising geological setting for gold mineralisation, such as in basaltic greenstones, the shear zone is next located on the ground.

3.2 Vapour geochemistry

Vapour geochemical traverses were made to test whether mineralised shear zones could be located on the ground using this technique. Though the use of vapour geochemistry to assist gold exploration has been advocated, to our knowledge it has not been widely utilised in Zimbabwe.

3.2.1 Carbon dioxide

Vapour geochemistry can be used in gold exploration to detect concentrations of sulphides which are commonly associated with gold and carbonate gangue minerals in the alteration haloes around shear-zone related gold deposits. Sulphide minerals decompose in the zone of weathering in reaction with aerated groundwaters. These reactions are particularly active at the water table. The simplified reaction sequence for sulphides, in particular pyrite, is as follows (Bateman 1959):

$$1)\ 2FeS_2 + 7O_2 + 2H_2O = 2FeSO_4 + 2H_2SO_4$$

The sulphuric acid reacts with the gangue carbonates to give carbonic acid which dissociates to liberate carbon dioxide:

$$2)\ H_2SO_4 + CaCO_3 = CaSO_4 + H_2CO_3$$
$$H_2CO_3 = CO_2\Uparrow + H_2O$$

The quantities of CO_2 produced by such reactions are such as to significently increase the CO_2 contents in the soil gas atmosphere (Lovell et al 1980) which can be detected even under desert conditions (Lovell et al 1983). These values can be detected using simple apparatus like the Orsat stack gas analyser (Fig. 1). The procedures for the determination of carbon dioxide and oxygen in soil gases described by Ball et al (1983) were followed.

A tubular steel probe was hammered into the ground and soil gas pumped into the Orsat apparatus using a rubber bellows. A volume of 100ml of soil gas was analysed firstly for carbon dioxide content by absorption in 40 percent potassium hydroxide solution and secondly for oxygen content through absorption in saturated ammonium chloride and ammonia solution reacting with coiled copper wire. The reagents are in the absorption chambers and the soil gas is moved around the apparatus by using the levelling bottle and stopcocks. The gas contents are measured in the burette and the results are available in 8-10 minutes. Once it had been established at Dalny that carbon dioxide and oxygen had an inverse relationship, carbon dioxide only was determined in several traverses, with considerable savings in time.

3.2.2 Radon and thoron

Radon and thoron determinations were made during certain traverses. It has been suggested that gold mineralisation in the Chakari shear zones is derived from geological plumbing systems connected at depth to plutonic source rocks (Foster et al 1979). The Whitewaters tonalite has been identified as a probable plutonic source of the gold. Tonalites contain accessory uranium minerals, and the

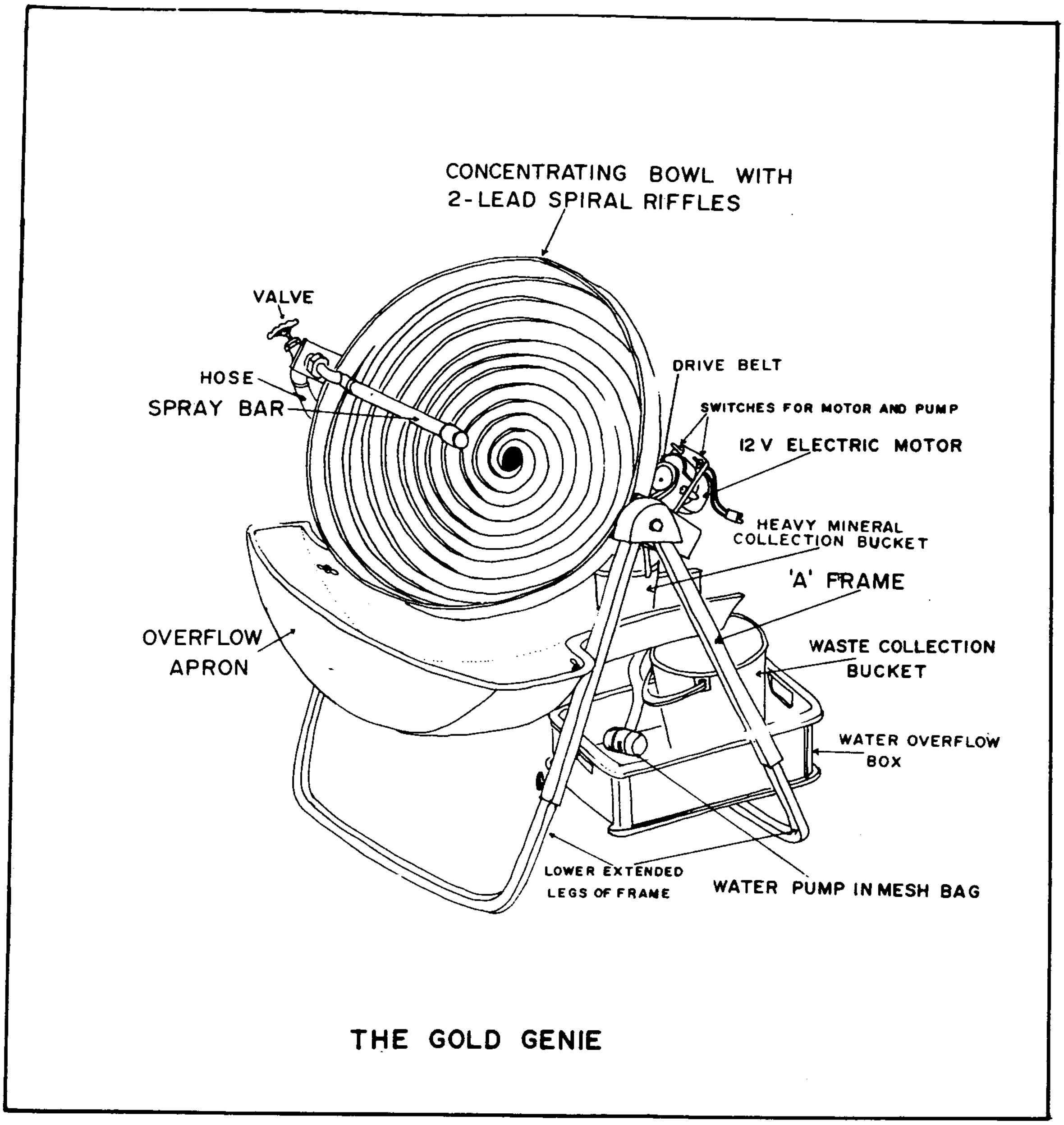

Fig. 2 The "Gold Genie" spiral concentrator.

mineralised shear zones, if rooted in such radioactive source rocks, might have had uranium minerals transported along them. Such uranium minerals could be the source of radon, the liberation of which would be enhanced if the shear zone is saturated with water (Tanner 1964, 1980). If this reasoning is correct mineralised portions of shear zones might be identified by anomalous radon values in soil gases directly over the shear zone.

Radon and thoron in soil gases were determined using an EDA RD-200 Radon detector connected to a soil gas probe. The total radon and thoron present was measured using a counting period of three consecutive one-minute intervals. A background reading of radon and thoron in atmospheric air was taken at each station and the amounts of radon and thoron in the soil gas calculated following the procedure described in the RD-200 manual.

3.3 Soil loaming for gold

In Zimbabwe loaming of soils in gold exploration has been used in the recent past (Morrison 1974) but has been superceded by direct chemical analysis for gold. Soil loaming gives a quick indication of the presence of gold, and has the advantage over chemical gold analysis that large samples can be handled, eliminating spurious results and false anomalies resulting from the 'nugget effect' (Clifton et al 1969).

The soil loaming method used in these trials was tested in Ghana earlier in 1987 by Crow and Laffoley (1988). It is described in more detail by Laffoley and Crow (1988). 15 litre soil samples were taken from 50cm deep pits in the consolidated B zone of the soil profile. This depth was chosen so as to be beneath the disturbed root zone and below any surface contamination. The soil samples were taken to Chakari Dam where they were wet-sieved through a 2 mm plastic sieve cloth held in a wooden frame. The -2 mm fraction was carefully washed clean of the clay and silt contents and the sample volume generally reduced by 70 - 90 percent. The heavy mineral concentrate obtained from this fraction was panned down to a volume of 150ml, thus achieving a x100 reduction in sample size. The heavy mineral concentrate was next washed onto a Gold Genie Spiral Concentrator (Fig. 2), which mechanically separated the gold particles from the less dense fractions. Finally the gold particles were counted on a black pan with a grid. The complete loaming process took about one hour for each sample.

Care has to be taken in the counting as with large numbers of gold particles there will be a tendency to underestimate the gold content.

Selected pan concentrates have been analysed for gold to find the detection limit of the method (Laffoley and Crow 1988). It was found that the analytical value below which particles of gold may not be found in a concentrate is 0.5ppm gold. Above this value gold particles are always present, while below it gold particles may not always be found.

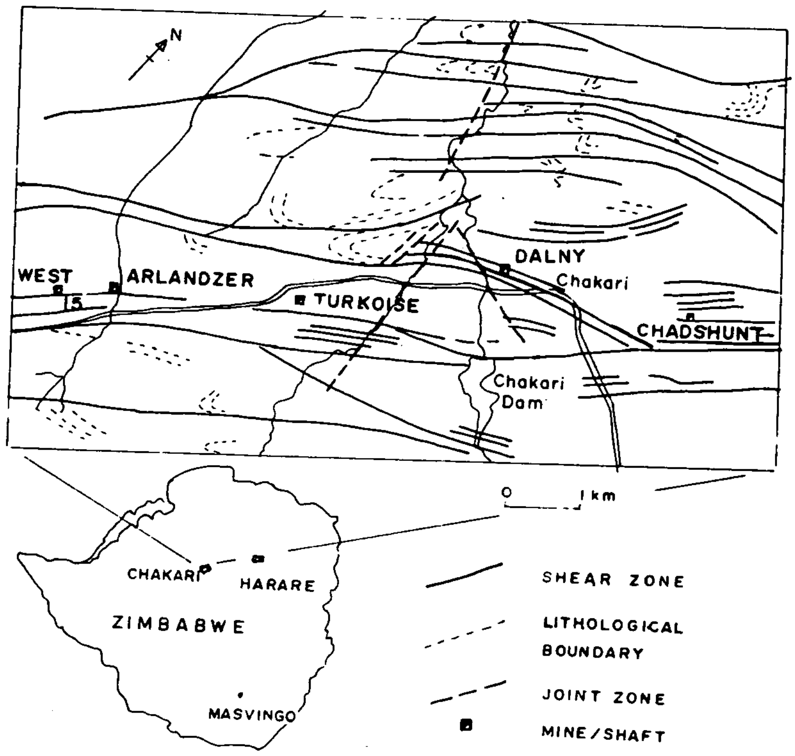

Fig. 3 Location map showing Dalny Mine and a photogeological interpretation of part of the Falcon Mines Ltd mining lease area.

4.0 OUTLINE OF THE GEOLOGY OF DALNY MINE

Dalny mine is the largest of the gold mines operated by Falcon Mines Ltd in their Chakari mining lease. Other deposits, worked at various times, are Chadshunt, Pixy, Turkois and Arlandzer. All the major gold deposits in the Chakari area are situated on shear zones (Fig. 3) which cut Archaean greenstones and metasediments of the Middle Bulawayan (Wilson 1979). The Bulawayan rocks are intruded by the large Whitewaters tonalite pluton to the southeast of Chakari (Bliss 1970).

The Dalny gold deposit is described by Foster et al (1979). The shear zone controlled ore bodies occur within massive and pillowed lavas of basaltic to andesitic composition and date from very early in the deformation sequence. The ore bodies are tabular lode-type deposits 0.1-10m in size dipping 70-80° to the north. The ore zones are composed of quartz and carbonate stringers associated with pyrite, arsenopyrite and other minor sulphides in strongly sheared and propylitised greenstones. Scheelite is present in small quantities throughout the ore body. The greenstone wall rocks of the shear zones have sericite-carbonate followed by chlorite alteration zones up to 7m wide. Pyrite and minor arsenopyrite occur close to the ore zone.

The topography of the Chakari area is subdued, with seasonally-dry streams cutting shallow valleys into the Post-African landsurface, dating from the Miocene (Lister 1979). Compared to the conical hills forming the "shear zone" topography around the Ashanti mine in Ghana (Crow and Laffoley 1988), the shear zones at Chakari have no distinct surface expression.

5.0 SELECTED RESULTS OF THE FIELD WORK

5.1 Aerial photographic interpretation

In order to eliminate complications caused by agriculture and mining in the Chakari area, the earliest available sequences of aerial photographs were selected for interpretation. These were flown in 1957 at a scale of about 1 : 20 000. An interpretation of the distribution of shear zones in part of the Chakari area is shown in Fig. 3. In this interpretation some "lithological boundaries" are taken to be tectonic on the grounds that they truncate other shear zones. Several tight folds of lithological boundaries are either sandwiched between, or are truncated against shear zones. Late northerly to north-westerly fractures or zones of close jointing form low topographic depressions which do not displace the shear zones.

5.2 Gold exploration orientation studies

Several orientation traverses were made over shear zones obscured by soils covered with grasses and low-bush. Soil types varied between residual sandy clays and seasonally waterlogged vlei-type soils. The soils were generally undisturbed but two traverses were made over hand dug small-holdings. The longest and most informative traverse known as Arlandzer #1 (Fig. 4), over undisturbed soils, is discussed in this summary.

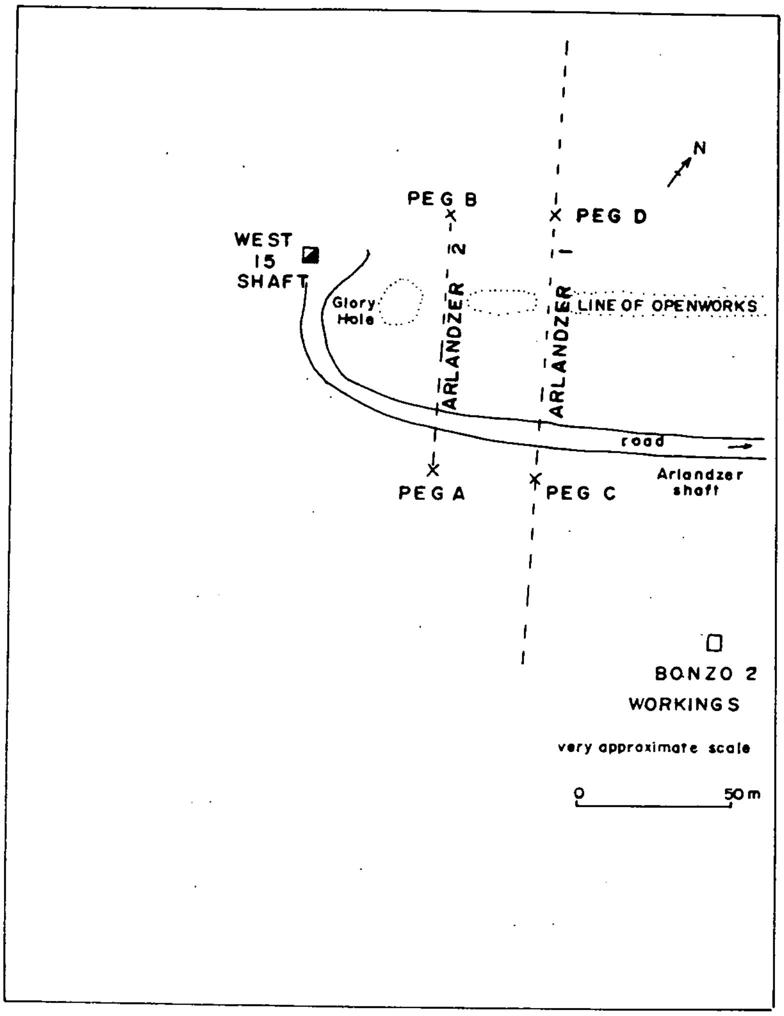

Fig. 4 Sketch plan showing the location of the Arlandzer traverses.

5.2.1 Vapour geochemistry: radon and thoron

Radon and thoron were determined in soil gases and the atmosphere at 3m spaced probe sites between Pegs C and D (Fig. 5). The results are typical of the radioactive gas traverses and show considerable local variation giving dentate graphical plots. The main Arlandzer shear zone at 99m was not detected, though the footwall reef between 129 and 150m appears to be defined by both thoron and radon peaks. It is suggested that this is caused by this reef being "wetter" than the main Arlandzer shear zone. The presence of water in the reef-zone would facilitate the emission of radon and thoron (Tanner 1964, 1980).

As the radon and thoron peaks are coincident it is probable that the parent radioactive source is very close to the surface. This is because the very short life of thoron (52 seconds) means that it cannot travel far from its parent source.

5.2.2 Vapour geochemistry: carbon dioxide and oxygen

Carbon dioxide contents of soil gases are available for the entire traverse whilst oxygen was determined only between Pegs C and D (Fig. 5). The carbon dioxide data picked up the Arlandzer shear zone (at 99m) as a broad anomaly between 93 - 108m, and small hanging wall anomalies between 81 - 93m and 60 - 69m. A separate hanging wall anomaly was found between 9 - 21m. The footwall anomaly between 129 - 150m was also recognised in the Arlandzer #2 traverse.

The carbon dioxide anomalies are well-defined and rise from a background of zero. Although readings were taken on three days over a period of three weeks there was no variation in carbon dioxide duplicates and the soil gas atmosphere appeared to be stable, possibly due to the dry weather conditions.

The carbon dioxide anomaly over the Arlandzer shear zone is low, rising only to 0.4ml. It is likely that the size of the carbon dioxide anomaly is related to the amount of sulphides present in the shear zone and possibly its degree of wetness. The largest carbon dioxide anomaly of 0.8ml is present between 204 - 238m and is spatially associated with the Bonzo 2 shaft and surface workings. This anomaly is thought to be caused by sulphide mineralisation associated with very minor gold values since the anomaly is accompanied by a very low particulate gold count (Fig. 5).

5.2.3 Gold loaming

The soil samples for gold loaming were collected in shallow (50cm deep) pits dug at 3m intervals between Pegs C and D. The traverse extensions to the east and west of the pegs were sampled at 6m and 9m intervals (Fig. 5). The traverse was extended with the intention of reaching a background of zero gold particles in soils. This objective was not achieved.

The highest particle gold count was obtained at 99m coinciding with the Arlandzer shear zone. Smaller gold particle peaks at 72m and 84 - 87m define hanging wall reef zones. The foot-wall reef at 135m, also defined by carbon dioxide and radioactive gas anomalies, had only been noted previously as minor gold values in exploratory drill core drilled underground.

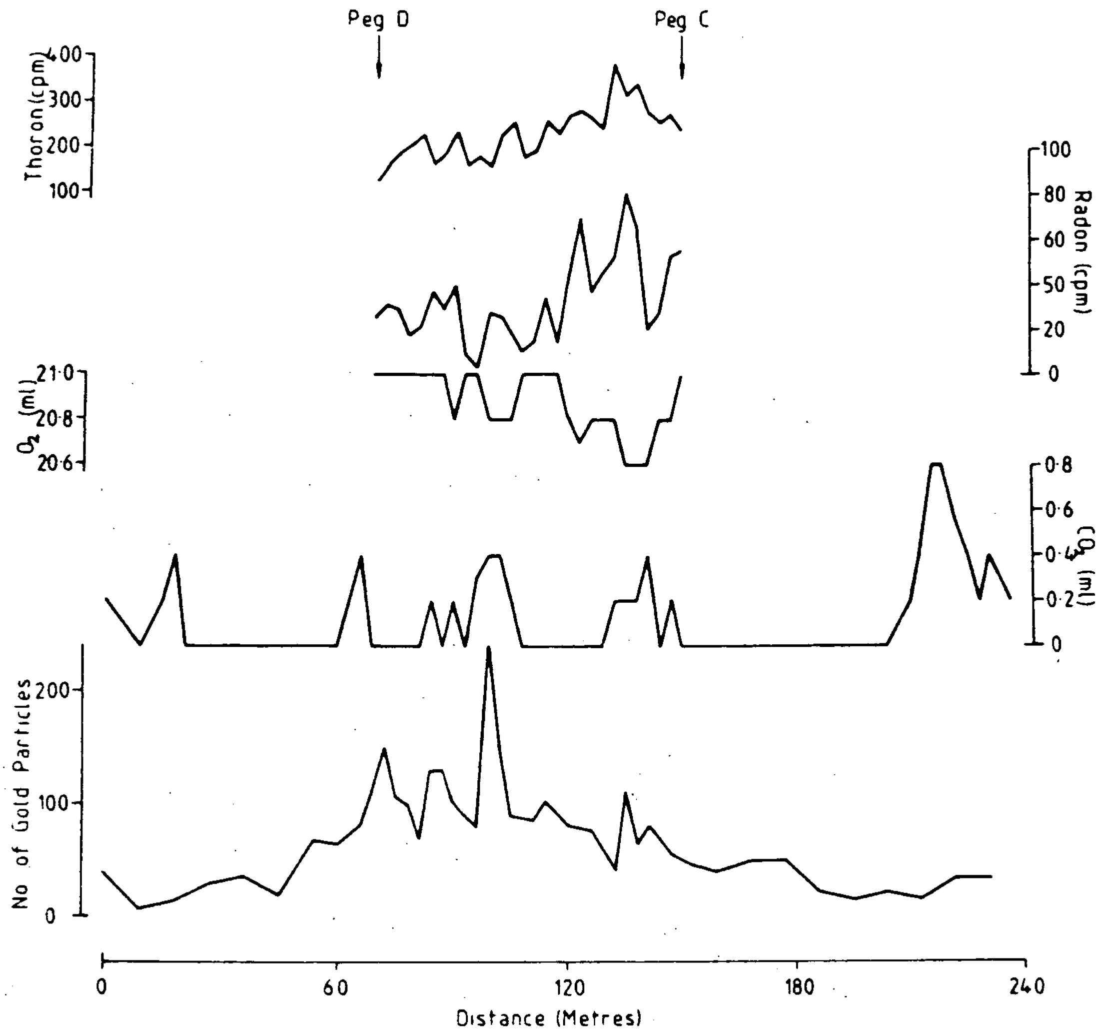

Fig. 5 The Arlandzer 1 traverse showing values for thoron, radon, oxygen and carbon dioxide in the soil gas atmosphere and counts of gold particles.

The association of the Arlandzer shear zone and this footwall reef with the high gold particle contents in the soils strongly suggests that the gold particles in the soils are derived from the gold mineralisation in the rocks from which the soils are derived. The fact that the zero gold particle background was not found may be due to the widespread distribution of gold at parts per billion level in the soils, perhaps related to the long-duration weathering effects. Whatever the reason for this phenomenon it provides wide exploration targe:s for major gold mineralised shear zones. For wxample at the Arlandzer shear zone, the zones of elevated gold values extend for 60m on either side of the mineralisation.

5.2.4 Discussion

With three exceptions the peaks of carbon dioxide anomalies and gold particle counts correspond . The carbon dioxide peak at 66m is displaced 6m from the gold particle peak at 72m and the carbon dioxide anomaly between 204 - 238m is not associated with enhanced gold particle counts, possibly because the mineralisation is caused by sulphides only. This example illustrates the value of soil loaming for gold in quickly distinguishing sulphides-only from sulphides-with-gold mineralisation, whether the sulphide anomaly is detected by geophysics or vapour geochemistry. To summarise no gold peaks were missed in the gas traverse, though extra targets were presented for verification by the soil loaming.

5.3 Gold exploration exercise

The orientation exercises over undisturbed and disturbed soils overlying blind mineralised shear zones demonstrated that the Integrated Gold Exploration system was working successfully. It was decided next to tackle an actual exploration problem. Accordingly, Mr S Twemlow, Chief Geologist of Falcon Mines Ltd. suggested that the southwest extension of the Chadshunt shear zone (Fig. 6) be explored; it has no surface expression as it lies beneath a ploughed field. As Chadshunt Farm is owned by Falcon Mines Ltd. there was no objection to the exploration exercise taking place though it was understood that the work would be conducted quickly and with minimum disturbance to farm work.

The first traverse, K - L (Fig. 6), was an orientation traverse close to the Chadshunt Inclined Shaft. Two strong carbon dioxide anomalies at 18m and 27m were found to be associated with elevated gold particle counts in soils collected from 50cm deep pits. As this was an exploration exercise the background values for gold were not determined.

The second traverse (M - N) in the ploughed field also showed strong carbon dioxide anomalies associated with gold particle values. The third traverse (O - P), some 50m southwest of M - N, gave only zero carbon dioxide values. suggesting that no mineralisation was present at depth. In order to locate the mineralisation, which might have been displaced by a fault, two infilling traverses were made. In the fourth traverse (Q - R) ragged carbon dioxide values rising to 0.4ml were recorded which in the fifth traverse (S - T) had coalesced into a single peak of 0.2ml. This might be taken to indicate that the mineralisation decreased in sulphide content southwest of traverse Q - R and died out in a space of 12m. Alternatively a fault may be present between traverses S - T and O - P, possibly a south-west dipping normal fault with a sinistral displacement component (S Twemlow, pers. com.).

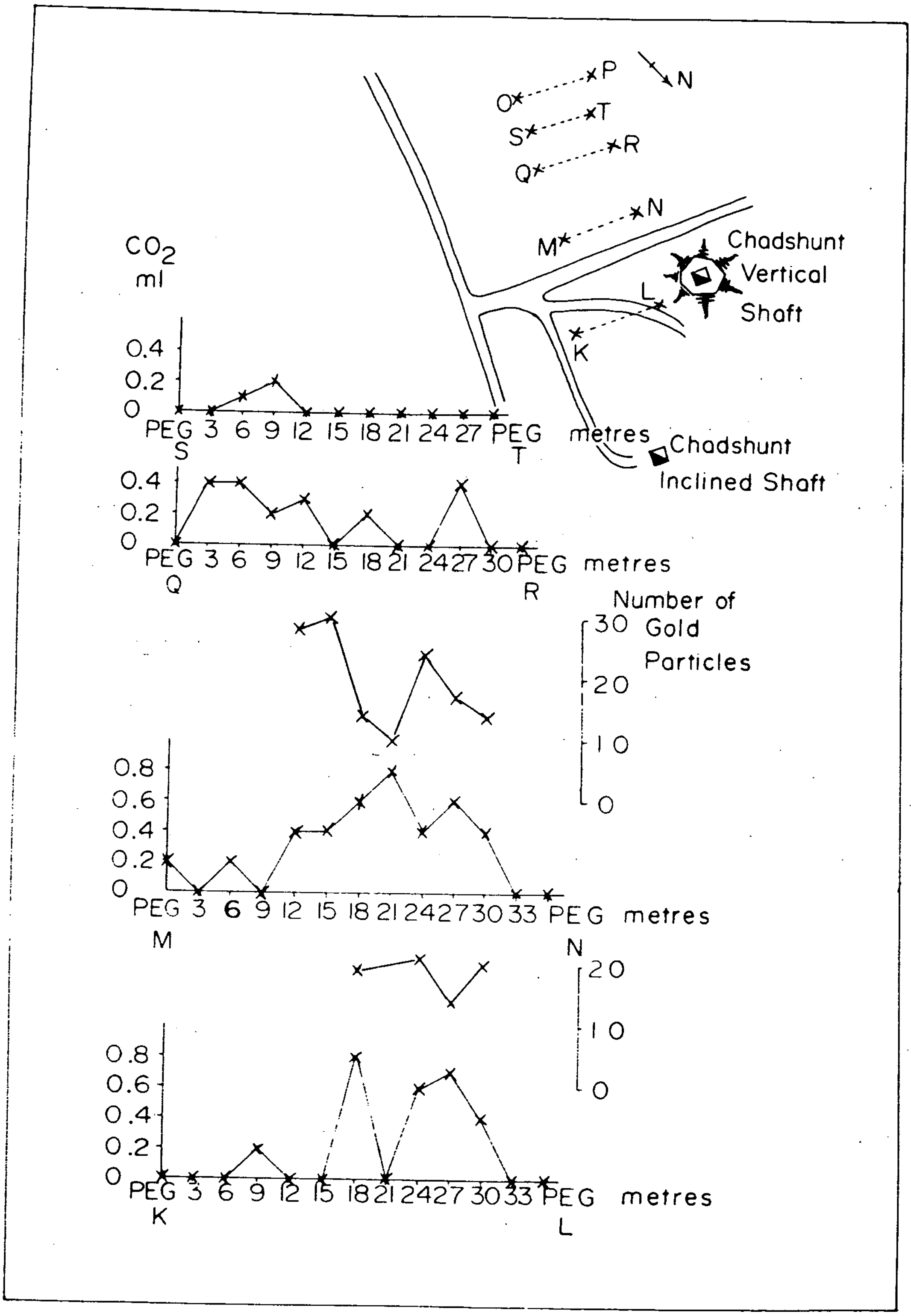

Fig. 6 Location of traverses at Chadshunt farm and results for carbon dioxide in the soil gas atmospheres and gold particle counts.

The soils loamed from Chadshunt were different to those encountered previously in the Chakari area. The Chadshunt soils were dark brown clays with deep surface cracks. The 50cm deep samples were collected from beneath the ploughed zone and it did not appear that the ploughing, if deeper, had affected the gold particle distribution above the shear zone. It is of interest that the soils in traverse M - N produced much coarser, well-rounded gold particles than had been recovered previously in either Zimbabwe, Ghana or the UK (Leake et al 1988).. The largest particle was approximately 2.5mm in size, compared to the average of 0.2mm. There would appear to be a relationship to the soil type; the Chadshunt soils resemble vlei-type soils and it is likely that the area is subject to seasonal waterlogging, perhaps explaining the local growth of atypical, larger gold particles.

6.0 DISCUSSION AND CONCLUSIONS

The exploration trials of the Integrated Exploration System of gold exploration were successfully conducted in a 'semi-arid' environment. The orientation phase showed that shear zones formed lineaments which could be recognised on aerial photographs (readily available in Zimbabwe); that sulphide-mineralised sections of shear zones gave off anomalous carbon dioxide soil gas, and that the residual soils above such shear zones contained gold particles which could be separated out by loaming.

It was confirmed that shear zones with high-grade gold mineralisation have extensive "shoulder zones" of elevated gold values on either side of the anomalous central zone which could be confidently recognised using the soil loaming technique.

Finally in the exploration exercise, a mineralised shear zone was traced into a ploughed field with the minimum of disturbance to farm work. This demonstrates that soil gas geochemistry is a useful method for exploring ground, such as farm land, which the owner does not want disturbed.

The vapour geochemistry, in particular the CO_2 gave satisfactory results at Chakari. However the generation of CO_2 in the zone of oxidation is very dependent upon the amount and activity of the groundwaters. It is possible that later on in the dry season the CO_2 results would become meaningless. This was found at the close of the dry season in Ghana in early 1988 by Crow and Piper (1988). However, as soon as the rains started, the CO_2 results were again strongly controlled by the oxidation of sulphides.

The control of climatic factors on vapour geochemistry may discourage its use in exploration. However when the soil gas atmosphere is influenced by the decomposition of sulphides, as is easily verified, it is a fast geochemical method giving immediate results.

The use of airphoto interpretation and soil gas geochemistry will be of most interest to exploration companies who have ready access to the commercial geochemical laboratories and so have no requirement for soil loaming. The gold-loaming technique will be of most interest to the prospectors and small-scale miners in their exploration for gold and evaluation of claims. It is a well-known technique in Zimbabwe, used more in the past than in the present. The improvements due to large sample size and use of a spiral concentrator make it a powerful exploration method capable of detecting gold values in soils, even over low-grade deposits (1-5g/tonne), with a very high degree of certainty. However its lower detection limit of about 0.5ppm gold means that the background gold values will not always be picked out. This emphasises the need to focus this method as far as possible on the target and reinforces the advisability of prior aerial photographic interpretation and soil gas traversing.

Support of small-scale miners and prospectors is important in Zimbabwe for two reasons. Firstly, small-scale mining is labour intensive and important in the rural economy as an alternative or a supplement to farming incomes. Secondly, with low-levels of commercial exploration, mineral companies are very dependent on prospectors successfully finding new gold deposits and selling this information to companies. While previously the exploration impetus was for high-grade deposits, new techniques of gold recovery like heap leaching now make low-grade gold deposits of the type sometimes found by prospectors economic to develop if they are large enough.

7.0 ACKNOWLEDGEMENTS

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