INTEGRATED LITHOSTRUCTURAL MAPPING OF THE RÖSSING AREA, NAMIBIA, UTILISING REMOTELY SENSED DATA

Helen Anderson# and Colin Nash*
 # Normandy Limited, 8 Kings Park Road, West Perth, Western Australia, 6005
** World Geoscience Corporation Limited, 65 Brockway Road, Floreat, Western Australia, 6014*

ABSTRACT

An integrated appraisal has been carried out of recent high-resolution aeromagnetic, radiometric and remote sensing data over the Rössing mine area and the lower Khan Gorge region of Namibia. Image processing and interpretation of the high resolution geophysical data provide a fresh overview of the complex structure within the Damara orogenic belt, notwithstanding the regolith cover.

Structure around the Rössing uranium mine was interpreted from stereoscopic aerial photographs and the regional structural setting was interpreted from high-pass filtered aeromagnetic data. Spectral Landsat® TM data, total field magnetic intensity data and imaged airborne gamma-ray spectrometer data enabled the delineation of lithology. Interpretation maps from those data clearly show an hierarchy of polyphase folding, which had been described by earlier field mapping, and a hitherto-unrecognised system of late (post-F3) north-northeast-oriented sinistral strike-slip faulting and associated northeast-oriented, southeast-vergent thrusting. Rotation of F3 fold axes from northeast to north-northeast orientations is common, and the overturning of F3 fold axes to the south of the Rössing mine may also be due to post-F3 transport.

Early Palaeozoic alaskitic intrusions of the type which host the world-class Rössing uranium deposit appear to be largely related to late sinistral transtensional ladder veins associated with the north-northeast-trending post-F3 sinistral strike-slip faults. Although these structures displays sinistral movement in the gross structural framework, it appears that these may also have been reactivated with minor transtensional (dextral) movement that controlled the emplacement of the alaskites. The actual Rössing alaskite dyke swarm appears to be located within an east-northeast-trending jog along a regional north-northeast-trending structure, which separates two regions of completely different structural styles. It is clear that the recognition of these later post-folding events has important implications for understanding the controls on mineralisation in the area, and thus exploration for further mineralisation.

Keywords: Rössing, Namibia, uranium, alaskites, interpretation, Landsat ®,aeromagnetic, aerial photographs, transtensional, lithostructural.

INTRODUCTION

The deeply incised gorge country around the lower Khan Gorge in the Rössing area of Namibia provides exceptional outcrops with local relief in excess of 200 m. However, plateau areas to the north and south of the Gorge are variably obscured by regolith and are difficult to map. Therefore, interpretation of a combination of remotely sensed data is required to obtain coherent geological coverage of the area.

The Precambrian basement to the Damara orogenic belt is composed of metamorphic rocks and anatectic granites (Abbabis Gneiss/Red Gneissic Granite) which occur in cores of large anticlinal structures. This is overlain by the Neoproterozoic Pan-African Damara Sequence, which includes a lower predominantly clastic unit (Nosib Group) and an upper carbonate-shelf unit (Swakop Group). The Damaran rocks were extensively deformed and metamorphosed to amphibolite–granulite transition grades during polyphase deformation in latest Proterozoic to early Palaeozoic times (650 Ma to 460 Ma). The lower Khan Gorge area is one of the world's classic locations to observe refolded folds (Figure 1). Interference structures were first mapped by Smith (1965), who noted the consistent northeasterly plunge of many polyphase folds and concluded that early northwest–southeast trending folds were refolded around later northeast-oriented F3 structures with predominantly vertical axial planes. The Rössing Mountain folds provide a classic example of F2/F3 interference. Jacob (1974) and Jacob *et al.* (1983) reached similar conclusions from a study of the Swakop Gorge area to the south, as well as recognising a third folding event. That event produced open folds with west-northwest to northwest-oriented axial planes, and rotated F3 structures into northeast trends.

Uraniferous S-type alaskites and associated anatectic granitoids were emplaced after peak metamorphic conditions and have sharp contacts with country rocks (Nash, 1971). The Rössing alaskite, which has an Rb–Sr age of 458±8 Ma

(Marlow, 1983), is the youngest of this group of rocks and hosts the world-class Rössing uranium deposit.

Berning (1986) described the structural setting of the Rössing orebody as the northern limb of a complex northeast-trending synclinorium. However, little else has been published regarding the structural controls of alaskite emplacement.

High resolution aeromagnetic and radiometric data (250 m line spacing, 80 m flying height, north–south traverse lines) were acquired in 1995 over the Rössing area in central Namibia by World Geoscience Corporation (location shown in Figure 1). The data were acquired on behalf of the Geological Survey of Namibia as part of a European Commission funded project. This paper concentrates on the new lithostructural information provided by high-pass filtered aeromagnetic data and radiometric data, in conjunction with existing remote sensing data, and examines the implications of this new information with regard to the structural control of primary uranium deposits in the Rössing area. This work was initially presented at the 12th ASEG conference in Sydney, Australia in February of 1997 (Anderson and Nash, 1997).

LITHOLOGICAL MAPPING

Individual lithological units can be mapped using the Landsat® TM satellite imagery and radiometric data. The thick marble units of the Swakop Group shelf sequence are distinctive in both datasets — recognisable as a characteristic blue colour in false-colour Landsat® images (B:G:R=TM1:TM4:TM7), indicating high albedo and probable absorption of TM band 7; and appearing darker than the surrounding sedimentary units on the ternary radiometric image (B:G:R = U:Th:K), indicating a lower radiometric signature. This enables the mapping of earlier folds which have been refolded during the later northeast-oriented F3 structural event.

The basement rocks (Abbabis Gneiss/Red Gneissic Granite) form a characteristic reddish Landsat® expression (strong TM band 7), which suggests anomalous iron content. They also have a high total count radiometric response, appearing as white or blue (high uranium) on the ternary images. Of particular importance is the identification of the alaskites and pegmatites around the SJ Dome due to their distinctive pink colour in the ternary radiometric image, indicating high potassium content.

Particular lithomagnetic units, such as the calc-silicate rocks and amphibolites of the Khan Formation (upper Nosib Group) within the Damara Sequence, exhibit quite high magnetic susceptibilities. A first vertical derivative image of the aeromagnetic data shows particular lithological units and the SJ Dome (Figure 2), as well as reinforcing the appearance in images of the fold patterns discussed above. In addition, the magnetic units can be traced beneath the sand plains, thus increasing geological knowledge in areas of little or no outcrop.

STRUCTURAL FRAMEWORK

This study has examined the structural setting of the Rössing area using qualitative interpretation of the aeromagnetic data supported by stereoscopic aerial photograph interpretation. Major structures, such as fold closures and faults, were interpreted following the delineation of short-wavelength magnetic trends in first vertical derivative greyscale images.

An overview structural interpretation of the aeromagnetic data in the lower Khan Gorge region is in Figure 1. There is clear evidence in the aeromagnetic data for regional north-northeast-oriented sinistral strike-slip faulting which cuts across and reorientates northeast-oriented regional (F3) folds to a more north-northeast trend. Thrust faults trending northeast and verging southeast are linked to the regional north-northeast-trending sinistral shears. No suggestion of either wrench or thrust faulting is indicated on existing mapping of the lower Khan Gorge area.

The more detailed interpretation of 1:50 000 scale stereoscopic aerial photographs within the eroded Khan Gorge region (Figure 2) strongly supports a post-folding shearing event characterised by north-northeast-oriented sinistral wrench faulting and east-northeast-oriented southeast-vergent thrusting. The interpretation shows a major northeast- to north-northeast-oriented sinistral shear zone which probably passes through the Rössing alaskite swarm, effectively rotating and cutting off the north-northeast-oriented fold axes of the SJ Dome and the parallel anticlinal structure to the east. Major folds, such as the Welwitschia Syncline (and the adjacent Camp Anticline to the north of Welwitschia Syncline), are all oriented east-northeast to northeast and display northwest-dipping axial planes, implying overturning. This contrasts with the SJ Syncline, immediately south of the Rössing mine, whose axial plane dips steeply to the south (Nash, 1971). This major change in structural trends, coincident with the interpreted structure passing through the Rössing alaskite swarm, is regarded as evidence for a regional detachment surface trending through the mine area with associated southeast-vergent thrusting. The post-folding north-northeast-oriented sinistral shear zones frequently occur as shear couples and control emplacement of alaskite “ladder vein” arrays.

The results of this combined interpretation of aeromagnetic data and aerial photographs suggest a hitherto-unrecognised regional shear event (F4?) which has effectively caused re-orientation of northeast-oriented F3 folds, which in turn refold earlier structures. Post-F3 shear-related structures appear to be mainly north-northeast-oriented sinistral faults and northeast-oriented, southeast-vergent thrust ramps. Rotation of F3 fold axes from northeast to north-northeast orientations is common, and the overturning of F3 axes in the Welwitschia Syncline and Camp Anticline region (Figure 2) may also be due to post-F3 transport.

STRUCTURAL CONTROL OF ALASKITES

Corner (1983) and Jacob *et al.* (1986) recognised a major north-northeast-oriented (F4) magnetic lineament in the central Damara Orogen from the pre-existing regional 1.5 km aeromagnetic data. The regional interpretation suggests that this major lineament is actually a series of en-echelon sinistral strike slip faults associated with late (post-F3) evolution of the Damara Orogen. Most uraniferous alaskites in the Rössing area are located near this major north-northeast-trending lineament, and locally folds are also parallel to this structure.

The alaskitic intrusions in the lower Khan Gorge region are clearly visible on aerial photographs owing to their light tone and topographic relief. The interpretation of the aerial photographs (Figure 2) shows that the actual Rössing alaskite swarm appears to be located within a northeast to east-northeast-trending jog along the regional post-folding north-northeast-trending sinistral strike-slip fault structure. Overturning of folds to the south of this structure implies local southeast-vergent thrusting as part of the regional transpressional event. However, the geometry and emplacement of the alaskite also suggests a phase of transtensional movement. Regardless, of which interpretation is correct, this structure probably represents a major late-stage detachment separating two regions of different structural styles. It is also clear from the interpretation of the aerial photographs (Figure 2) that many of the other alaskitic bodies occur as "ladder vein" intrusions between north-northeast-trending shear fault pairs. These imply that the structures appear to have been active during a transtensional (dextral) event, during which many alaskites were emplaced as ladder vein sets. This is in contrast to the sinistral movement suggested by the gross structural framework. Further field work is required to determine the movement history on the structures but this work suggests that the major phase of sinistral movement was followed by minor dextral reactivation or relaxation of the structures.

CONCLUSION

The integrated interpretation of high resolution geophysical data and other remotely sensed data over the Rössing uranium mine in Namibia has provided both an overview of the regional structure and further insight into possible structural controls on the alaskitic intrusions which host the uranium mineralisation.

Interpretation maps clearly reveal an hierarchy of polyphase folding, which had been described by earlier field mapping, and a hitherto-unrecognised system of late (post-F3) north-northeast-trending sinistral strike-slip faulting. East-northeast-oriented, southeast-vergent thrust ramps are associated with the faulting, and rotation of the earlier fold axes into the later structures is also common. The early Palaeozoic alaskite body which hosts the Rössing uranium deposit appears to be located within an east-northeast-trending jog along a regional north-northeast-trending structure, which separates two regions of different structural style, and thus may represent a detachment structure. Other alaskitic intrusions appear to be largely related to late sinistral transtensional ladder veins associated with the north-northeast-trending post-F3 sinistral strike slip faults. Thus the recognition of this later post-folding event has important implications for understanding the controls on mineralisation in the area, and thus exploration for further mineralisation.

ACKNOWLEDGEMENTS

The geophysical data shown in this paper are published with the kind permission of the Geological Survey of Namibia and World Geoscience Corporation. This work was initially presented as an oral and extended written presentation at the 12th ASEG Conference in Sydney, Australia in February 1997.

REFERENCES

Anderson, H.F. and Nash, C.R., 1997. Integrated lithostructural mapping of the Rössing area, Namibia, using high resolution aeromagnetic, radiometric, Landsat data and aerial photographs. *Exploration Geophysics*, **28**, 185-191.

Berning, J., 1986. The Rössing uranium deposit, South West Africa/Namibia, pp. 1819-1832 *In* Anhaeusser, C.R. and Maske, S., eds, *Mineral deposits of southern Africa.* Geological Society of South Africa, 2 vols, 2335pp.

Corner, B., 1983. An interpretation of aeromagnetic data covering the western portion of the Damara Orogen in South West Africa/Namibia, pp. 339-354 *In* Miller, R. McG., ed., *Evolution of the Damara Orogen of South West Africa/Namibia*. Geological Society of South Africa, Special Publication, **11**, 515pp.

Jacob, R.E., 1974. Geology and metamorphic petrology of part of the Damara Orogen along the lower Swakop River, South West Africa. Bulletin of the Precambrian Research Unit, University of Cape Town, **17**, 185pp.

Jacob, R.E., Corner, B. and Brynard, H.J., 1986. The regional geological and structural setting of the uraniferous granitic provinces of southern Africa, pp. 1807-1818 *In* Anhaeusser, C.R. and Maske, S., eds, *Mineral deposits of southern Africa,* Geological Society of South Africa, 2 vols, 2335pp.

Jacob, R.E., Snowden, P.A. and Bunting, F.J.L., 1983. Geology and structural development of the Tumas basement dome and its cover rocks, pp. 157-172 *In* Miller, R. McG., ed., *Evolution of the Damara Orogen of South West Africa/Namibia*. Geological Society of South Africa, Special Publication, **11**, 515pp.

Marlow, A.G., 1983, Geology and Rb-Sr geochronology of mineralised and radioactive granites and alaskites, Namibia, pp. 289-298 *In* Miller, R. McG., ed., *Evolution of the Damara Orogen of South West Africa/Namibia*. Geological Society of South Africa, Special Publication **11**, 515pp.

Nash, C.R., 1971, Metamorphic petrology of the SJ area, Swakopmund District, South West Africa. Bulletin of the Precambrian Research Unit, University of Cape Town, **9**, 77pp.

Smith, D.A.M., 1965, The geology of the area around the Khan and Swakop Rivers in South West Africa. Geological Survey of South Africa Memoirs (SWA Series), **3**, 113pp.

Figure 1. Structural Interpretation of the Lower Khan Gorge region, based on aeromagnetic data and aerial photgraphs, showing dominant post-F3 northeast to north-northeast-oriented sinistral wrenching. The location of Figure 2 is shown.

Figure 2. Structural interpretation of 1:50 000 scale stereoscopic aerial photography over the Rössing mine area. (location shown in Fugure 1)

GHANA, A COUNTRY IN TRANSITION: AN EXPLORATION PERSPECTIVE

Ian Blayden
Independent Consultant/GMS Pty Ltd and Director – Takoradi Gold N.L.
19 Debs Parade, Dudley, 2290

INTRODUCTION

Takoradi Gold N.L. (Takoradi) is an Australian listed company with all its exploration assets located in Ghana. The company has been exploring actively in Ghana since 1987, prompted by the vision and foresight of Bruce Cozens, the company's founder and first Managing Director (now deceased). At that time the economy of the country was stagnant and the infrastructure was severely run down. With the aim of revitalising the economy and rebuilding the infrastructure the government had (at that time) only recently instituted the Economic Recovery Programme (ERP) designed to open the country to foreign investment, lift exchange controls and privatise the extensive network of government enterprises. Bruce had long recognised the exploration potential of the country and had faith in the ability of the government to re-establish what was once a vibrant and diverse economy.

The ERP has largely been a success. In 1987 there were perhaps two or three foreign exploration companies in the country, no commercial laboratories, no resident drilling companies, little in the way of heavy equipment suppliers and generally very poor roads. There was limited and erratic availability of electricity, water and telephones. In contrast the situation in 1997 is vastly different. Exploration acreage is now at a premium — with many foreign companies, including multinationals, actively exploring. All but the most sophisticated exploration services are available in the country. The sealed road network is much more extensive, as is the electricity grid. Blackouts and water supply interruptions are now very infrequent. Telephone services are more widespread, fully automatic and include mobile as well as radio telephone facilities.

Takoradi, as a company, did not respond well to this rapidly changing environment. Being on the ground early there was the potential to establish a much stronger and more pre-eminent position than it now has. Nonetheless the company is still exploring and has the potential to define and develop significant resources. The purpose of this paper is to review the exploration history of Takoradi in the light of the changing environment and derive some lessons for companies contemplating activities elsewhere in Africa.

Company history

Takoradi Gold N.L. has been an active gold explorer in Ghana since the formation of the company in 1987. From 1987 until delisting of the company in 1992 the principal focus of activity was on the Kutukrom Concessions in the Western Region, 200 km west of Accra (Figure 1). During that time most of the exploration funds were directed towards detailed examination of old hard rock mining areas on the southwesterly extension of the Prestea line of lode. This work was principally in the form of adit rehabilitation and development and resulted in the identification of the Insamankaw Mine area (Figure 2) as a potential drill target. Since relisting in 1993, Takoradi has carried out a program of regional exploration and drilling which has identified several other target areas.

As part of a restructuring and relisting in 1993 Takoradi entered into a joint venture on two exploration licences (Yakomba and Baju) and a reconnaissance licence (WakaWaka) located in the Northern Region, south of Bole, 500 km northwest of Accra (Figure 1). The area contains a number of old mines and from early 1994 Takoradi has carried out an extensive program of exploration which has included both regional investigations and detailed studies of the old mining areas. Drilling programs were carried out on the old mine sites in 1994 and 1995 and on newly identified targets in 1997.

Operational structure and facilities

To carry out the exploration programs Takoradi has established an office and residence in Accra and a substantial permanent field camp at Kutukrom. Permanent field camps have also been established in the Yakomba and Baju Concessions, as well as an office/residence in Bole. The local management, geological and field staff consist entirely of Ghanaian nationals.

Communication between the Accra office, Kutukrom and the Bole area is by VHF radio and/or radiotelephone.

REGIONAL GEOLOGY AND MINERALISATION

The geological framework of Ghana may be divided into five principal tectonic units.

- The **West African Shield,** which contains rocks of early Proterozoic age, underlies much of Ghana and extends into the neighbouring countries of Burkina Faso to the north and Côte d'Ivoire to the west.
- The **Pan-African Foldbelt** occupies the southeastern portion of Ghana and is separated from the West African Shield by a major northeasterly trending thrust fault system. The fold belt consists primarily of gneissic rocks of the Dahomeyan Series but includes a sequence of quartzites, schists and serpentinites of the Togo Series. The Togo Series is probably younger than the Dahomeyan Series and is restricted to a narrow belt along the contact between the West African Shield and Dahomeyan rocks (Figure 1). The contact fault zone also contains a sequence of clastic and basic volcanic rocks of probable Proterozoic age referred to as the Buem Formation.
- The **Voltaian Basin** occupies a large area in the central eastern portion of Ghana and contains a gently folded sequence of clastic rocks from late Proterozoic to possibly Devonian age. Rocks of the West African Shield (Figure 2) underlie the Voltaian Basin sequence.
- The **Accraian Basin** and **Sekondian Basin** are two small basins containing clastic rocks of Devonian age. The basins developed in the coastal regions around Accra and Takoradi.
- The **Coastal Basins** include a number of small basins, which occur along the coastal areas of Ghana, containing clastic rocks of Late Jurassic to Recent age.

Gold mineralisation

The controls on gold mineralisation in Ghana have yet to be fully understood. Prior to the current surge of exploration activity (commencing in the 1980s), gold mineralisation was considered to be limited to three hard rock types and in alluvial deposits. The hard rock mineralisation was believed to occur only in rocks of Proterozoic age on the West African Shield (referred to as the Birimian System). The gold deposits were believed to be further restricted to a series of parallel supracrustal belts within this system. These belts have many similarities with the Archaean greenstone belts of Western Australia.

The Birimian System is divided into an Upper and Lower Series. The more extensive Lower Birimian Series consists of a substantial thickness of isoclinally folded and steeply dipping slates, phyllites and greywacke, with some tuffs and lavas. The Upper Birimian Series occurs as a sequence of infolded belts unconformably overlying the Lower Birimian Series and contains substantial thicknesses of basaltic, andesitic and rhyolitic lavas as well as agglomerate, tuff and tuffaceous sedimentary rocks.

The Birimian System has been intruded by an extensive suite of syntectonic potash-rich granitoids referred to as the Cape Coast granitoid complex and a younger, more discrete, suite of post-tectonic hornblende granite, granodiorite and diorite referred to as the Dixcove granitoid complex. Intrusion of both the Cape Coast and Dixcove granitoids was related to the Eburnean thermal event dated at between 2100 million years and 1800 million years.

Gold mineralisation was believed to be confined to the Upper Birimian belts. One of those belts, the Axim–Konongo Gold Belt (containing the Konongo, Ashanti, Canada Bogosu and Prestea mines) has been the principal source of historic gold production (Figure 1). The Ashanti Mine alone has produced in excess of 20 million ounces over a 100-year life, and currently produces in excess of 900 000 ounces a year.

There are two main modes of gold occurrence. One type is in the form of extensive, near-vertical high-grade reefs restricted to shear zones and often associated with carbonaceous horizons. The second type is in association with irregular disseminated sulphide bodies within the volcanic rocks. The two types can occur in close proximity to each other.

Widely developed within the Axim–Konongo Gold Belt, and locally elsewhere, is a thick sequence of rudaceous, arenaceous and argillaceous rocks of the Tarkwaian System. Those rocks unconformably overlie but are infolded with the Birimian rocks and are believed to be of late Proterozoic age. The basal Tarkwaian System also contains extensive gold mineralisation in the form of banket reef-type gold-bearing conglomerate. These rocks occur in a number of locations but are most extensively developed along the Axim–Konongo Gold Belt. Economic Tarkwaian orebodies occur only in the vicinity of Tarkwa where mines include Iduapriem, Teberebie, Tarkwa and Aboso (Figure 1).

A fourth mode of gold occurrence has been identified recently in the form of reef and stockwork zones in Dixcove granitoid bodies. This is the principal source of mineralisation identified by Clough Resources at Ayenfuri, also within the Axim–Konongo Belt, and may be the style of mineralisation for the newly discovered orebody at Obotan (Kennedy, this volume) in the Bibiani Belt. Takoradi has also identified mineralisation of this type.

There have been reports of gold and/or diamonds within the Dahomeyan rocks of eastern Ghana. How significant these occurrences are and their mode of development has yet to be ascertained.

KUTUKROM CONCESSION

Location and access

The Kutukrom Concession is located around the village of Kutukrom to the south of Prestea in the Western Region of Ghana (Figures 1 and 2). Prospecting Licence 8147/86, covering a total area of 56.86 km^2 was originally granted in the Kutukrom area in 1986. The initial concession included Mining Leases CV597 and CV598 of 14.56 km^2, which were excised from the licence area. The company subsequently negotiated an agreement with the leaseholders whereby it is entitled to a 70% interest in the leases.

The major drainage on the property is the Fure River, dividing the terrain into low-lying ground to the west and hilly ground to the east. The maximum elevation of the range to the east is in excess of 150 m. To the west the topography is much lower and seldom exceeds 60 m.

The Kutukrom area falls within the equatorial forest belt of Ghana. The areas to the west of Fure River and to the southeast are generally covered by old growth forest. To the northeast the original forest has been cleared and replaced by dense secondary bush or small farms. Cocoa is the main cash crop in the area, with farms concentrated along the banks of Fure River and valleys of secondary rivers. Food crops such as cassava, plantain, maize, beans and vegetables are also cultivated.

General geology

The Kutukrom area is situated on the Axim–Konongo Gold Belt on the southwesterly projection of the Prestea line of lode. There is extensive residual soil cover over most of the area and outcrop is generally poor. Distribution of the main rock types has been established from an intensive mapping program along a series of grid lines cut through the vegetation (Figure 2).

The Birimian System contains phyllites, greywackes and metavolcanic rocks. Greywackes are widely developed in the western part of the area. They are medium- to coarse-grained, quartzose, compact and massive in appearance, though occasionally schistose. The eastern portion of the area contains phyllites and metavolcanic rocks. The phyllites are usually fine-grained with some tuffaceous and carbonaceous components. The metavolcanic rocks are both acid and basic lavas with associated pyroclastic units.

Rocks in the Kutukrom area are steeply dipping, having been subjected to intense deformation. In the western part of the Concession the rocks strike in a northerly direction and dip to the west at between 55° and 70°. To the east of Fure River the rocks have a north-northeasterly strike, dipping 60° to 85° to the east.

Quartz veining is common on the property (Figure 2), sometimes forming prominent reef outcrops. They are steeply dipping and are developed in both the metasedimentary and metavolcanic rocks.

Note traditional units have been used for gold production, e.g.1 troy ounce = 31.1g.

Previous mining and exploration

Mining in the Kutukrom region by local people dates back several centuries. European exploration and mining activity commenced in the late 19th century, with underground mining known to have taken place at Insamankaw near Kutukrom over several years prior to the First World War. Operations at Insamankaw included underground workings on at least two levels but there are no records of tonnage or grade of the ore produced.

Other European workings in the form of collapsed shafts occur at Tintinah. Probably excavated prior to the First World War, they were developed on the site of extensive indigenous and Portuguese elluvial workings.

The bed of the Fure River, which traverses the Kutukrom area from north to south, was dredged between 1909 and 1913 to produce 0.42 grams of gold per cubic metre from 144 000 bank cubic metres of wash. Later dredging operations continued until 1921.

Takoradi exploration

Exploration in the Kutukrom Concession has been conducted in three phases. Phase 1 and Phase 2 were conducted prior to restructuring of the company in 1993. Phase 3 has been carried out since the restructuring.

Phases 1 and 2 comprised:

i) database search and planning;

ii) location and reclamation of old workings (adits, shafts, pits and trenches), mapping and sampling;

iii) preliminary trenching for zone continuity in areas with old workings;

iv) alluvial investigation; and

v) reconnaissance geological mapping and heavy mineral pan concentrate stream surveying.

That work was concentrated on the sites of previous exploration and mining and resulted in the identification of a number of potential drill targets. Other potentially prospective portions of the Concession remained unexplored and the objective of the Phase 3 program was to provide knowledge of the gold prospectivity of the area as a whole. Data from that phase were to be used in determining if all future prospecting should be directed at the obvious target areas, such as Insamankaw, or whether there may be other more subtle but potentially larger targets obscured by the dense vegetation and deep soil cover in the area. The exploration program included the following activities:

i) comprehensive geological mapping of the area ;

ii) trenching;

iii) geochemical soil surveying;

iv) a VLF-EM geophysical survey; and

v) reconnaissance drilling.

Mapping was carried out along a series of east–west traverse lines cut across both the Kutukrom and Tintinah areas. The traverse lines were 200 m apart and were up to 10 km in length. Generally outcrops are rare on the property, especially to the west of the Fure River. A number of exploratory trenches were also dug in key areas of poor outcrop to assist in the interpretation of the geology. To assist in the field identification of the rock types a number of thin sections were prepared of selected samples.

One significant observation in the Tintinah area was the unexpected identification of Dixcove type granitoid float. This was the first observation of this type of intrusion in the southern part of the Axim–Konongo Gold Belt and was considered to have considerable exploration significance. Much quartz float was observed during the mapping. Follow-up work involved tracing boulders and outcrops along strike, and a number of reefs were identified by this means.

The soil geochemical sampling program was undertaken over the same grid as that established for the regional mapping. Samples were collected 50 m apart on the east–west traverse lines. 673 soil samples were collected from the Tintinah prospect and 2127 from the Kutukrom prospect.

In the Kutukrom area gold values were obtained over a range of <20 ppb to 1400 ppb, whilst in the Tintinah area the gold values were in a range of <20 ppb to a maximum of 745 ppb. Apart from the northwestern part of the area where almost all the gold values are above the threshold of 50 ppb, the area contains only isolated high values surrounded by gold values below the detection limit of 20 ppb. Even in the southeastern portion, where there are many old workings and quartz reefs, most of the gold values are below the detection limit — although a few anomalies were observed which do not coincide with the suspected mineralised quartz reefs.

A ground VLF-EM field survey was undertaken over the established grid using a Crone Radem receiver. Readings were taken 20 m apart on traverse lines 200 m apart. A number of VLF anomalies were defined which coincided with areas of known mineralisation and/or were coincident with geochemical anomalies. A program of trenching was then carried out in the areas considered to be most prospective, leading to identification of a number of drill targets. Because of access restrictions to some areas most effort was concentrated on a zone south of Insamankaw and the old Tintinah workings.

In the Kutukrom area 16 trenches were excavated over a strike length of 1600 m south of Insamankaw (Figure 2). Mineralisation was generally of low grade although towards the south one trench (K6000N) revealed a zone averaging 2.61 g/t over 20 m. With the widespread and erratic nature of the mineralisation, a program of reconnaissance drilling was designed to evaluate the whole Insamankaw trend. Sixteen holes totalling 829 m were drilled with the best intersection being of 2.02 g/t over a width of 19 m from the interval 5 m to 24 m in hole 600C. The mineralisation occurs in sheared carbonaceous phyllite at the site of trench K6000N.

The mineralisation lies on the projected extension of the Prestea zone located to the north of the Kutukrom Concession but the style of mineralisation has affinities more with that at Canada Bogosu than at Prestea. Follow-up exploration has yet to be carried out.

Trenching in the Tintinah area proved difficult because of deep weathering and/or thick siliceous laterite. A reconnaissance drilling program of 16 holes for a total of 797 m was used to probe the area. The best intersections were 26 m averaging 1.56 g/t in hole TW1700A (Figure 3) and 8 m averaging 2.85 g/t in hole TW1300C. Hole TW1700A commenced and terminated in mineralisation at 30 m whilst hole TW1300C, located 400 m to the south, terminated in mineralisation at 60 m. The mineralisation is contained in quartz stockworks in highly altered granite, the first recorded occurrence of this type of mineralisation in the region. Follow up exploration has yet to be carried out.

BOLE CONCESSIONS

Takoradi is earning an 80% interest in three concessions in the Bole area: two Prospecting Licences, each of 150 km^2, referred to as the Yakomba and Baju Concessions, and the WakaWaka Reconnaissance Licence of 650 km^2 (Figures 1 and 4). The Yakomba Concession is located 20 km to the southeast of Bole and the Baju Concession is 60 km to the east-southeast of Bole. The Prospecting Licences were granted in early 1994 for an initial period of two years. The Reconnaissance Licence area covers the southern extension of the mineralised zone identified from prospecting in the Yakomba Exploration Licence.

Location and access

Bole, the principal population centre in the region, is 530 km north of Accra (Figure 1). Access to Bole from Accra is gained by fully sealed roads for a distance of 410 km through Kumasi and Techiman to the bridge on the Black Volta at Bamboi. A gravel road in moderate condition provides access from Bamboi to Bole, a distance of 110 km. The road from Techiman to Bole is part of a major trunk route from Ghana to northern Africa through Burkina Faso and it is expected that it will be fully sealed through to the border in the near future.

Bole is a major regional centre within the Northern Region of Ghana, with a population of about 2000. The town contains an Agricultural Research Station and a new hospital. An automatic telephone system has recently been installed and the area was connected to the national electricity grid in 1996. Other population centres consist of villages scattered along the Bamboi–Bole road. There are few villages in the bush away from the main road, two exceptions being the villages of Dokrupe and Kablima in the Yakomba Prospecting Licence (Figure 4).

The topography is gently undulating and is dissected by numerous small to medium drainage channels which are active only during the rainy season from July to September. Vegetation consists primarily of open savannah forest that is generally burnt off each year. There is small scale, essentially subsistence, agriculture adjacent to villages and towns.

Access to Dokrupe and Kablima is by means of a poorly maintained service road 19 km east of the village of Seripe on the Bole–Bamboi road through Dokrupe to Kablima (Figure 4).

figure 4

This road has since been partially upgraded as part of the exploration carried out by Takoradi. Access into the Baju Exploration Licence is by means of a previously abandoned track extending from Kablima for a distance of 35 km. This road has been reopened and upgraded by Takoradi. It is trafficable for most vehicles during the dry season but is passable only to high clearance 4-WD vehicles in the wet season.

Three field camps have been established to provide living and office accommodation in the area, one on the Baju Concession and two on the Yakomba Concession. The company has also established a four-room office/residence in Bole by refurbishing an abandoned but soundly constructed research clinic.

Regional geology

The Prospecting Licence areas are located on the southeastern extremity of the Bole Belt. The oldest rocks in the area belong to the Birimian System of early Proterozoic age and consist of a sequence of metasandstones, phyllites, schists, graphitic schists and metatuffs. There are locally developed greenstones probably derived from metamorphosed mafic volcanic rocks and intrusions as well as rocks of silicic volcanic provenance. The rocks are strongly folded, with the foliation primarily trending in a northeasterly direction.

Infolded with the Birimian rocks are the syntectonic Cape Coast type granitoids, which in this area are gneissic granite, diorite, granodiorite and amphibolite. Post-tectonic Dixcove granitoids occur as a series of stocks and batholiths throughout the area. The rocks include hornblende granite, quartz diorite, gabbro and syenite porphyry.

Flat-lying clastic rocks of the late Proterozoic age Voltaian System unconformably overlie the Birimian System rocks and occur locally in the eastern part of the Baju area. The Birimian sequence and intrusive rocks are disrupted by a series of transcurrent faults trending in a northeasterly direction across the area. These faults post-date the Dixcove granitoids but pre-date the Voltaian System rocks.

A lateritised soil profile, generally less than two metres thick, is developed over much of the Yakomba and Waka Waka area and is believed to have developed during the Pliocene or Pleistocene. This laterite appears to have been stripped by subsequent uplift and erosion in the Baju area.

Outcrop availability is moderate to poor, with the best exposures found in the areas where the laterite has been stripped and (more particularly in the dry season) after the vegetation has been burnt.

Yakomba Exploration Licence

The principal rock types in the eastern part of the Bole Concessions area are steeply dipping and isoclinally folded lower Birimian phyllites, carbonaceous phyllites and sandstones. Further to the west the sequence is similar but includes some pyroclastic and manganiferous rocks. The foliation in the rocks strikes in a northeasterly direction and the sequence is disrupted by a series of northeasterly trending wrench faults. Quartz veins up to 1 m wide and 100 m to 200 m in length are widely developed in the metasediments, generally parallel to the foliation.

An extensive body of Cape Coast granitoid intrudes the metasediments in the northeastern part of the area. The principal rock type is a silicified fine-grained and foliated biotite granite. In places the granite contains small elongate xenoliths of biotite schist and is extensively intruded by quartz–muscovite–plagioclase pegmatite veins. The veins do not appear to exhibit any particular orientation.

A stock of medium-grained quartz diorite, which forms part of the Dixcove intrusive complex, extends over an area of about 10 km^2 to the west of Dokrupe and has intruded the Birimian metasediments. Similar bodies are present on the southwestern boundary of the area near the village of Sakpa (Figure 4). The Dokrupe quartz diorite is dislocated by shearing in the southeast. That shearing is associated with chlorite–carbonate–pyrite–silicic alteration and gold mineralisation, with quartz veins and stockworks (Dokrupe deposit). Swarms of auriferous quartz veins are also locally developed at two locations within the quartz diorite to the north of the Dokrupe deposit and are referred to as the Thomas and Senyon Prospects.

Manganese mineralisation. Manganese-rich sedimentary rocks have been observed at a number of locations in the Bole area. A potentially economic deposit, enhanced by surface enrichment, is located 4 km east of Seripe on the Seripe–Dokrupe road just outside the Yakomba Prospecting Licence. That deposit is one of several in the region, which occur within a broad northeasterly trending zone.

The Seripe deposit occurs in a manganiferous bed 20 m to 23 m thick that strikes in a northeasterly direction for a distance of 750 m. It is located at the northern end of the zone containing the other manganese occurrences. A resource of about 900 000 tonnes has been estimated for the deposit but no grade or depth is stated.

Gold mineralisation. Gold mineralisation is associated with the zone of shearing, alteration and quartz veining at the southern end of the Dokrupe quartz diorite. There is also gold mineralisation associated with two quartz vein swarms developed within the intrusion. Reconnaissance drilling indicates that there may be similar styles of mineralisation associated with small isolated quartz diorite bodies to the south of Dokrupe and at Sakpa.

In the Dokrupe area the gold occurs primarily in quartz veins and stockworks, both in the quartz diorite and adjacent contact zone. Free gold is the principal form, generally fine but individual grains may be up to 5 mm. It is associated with minor pyrite, chalcopyrite and galena.

Past exploration and mining

In 1923/1924, two geological parties (Kitson et al., 1924; Teale and Whitelaw, 1925) carried out regional geological examination of the Kintampo and Bole Field Sheets, including the area covered by the Yakomba Application area. In 1927 Kitson (1928) also visited the Yakomba area as part of a more regional program.

Gold Coast Selection Trust (GCST) carried out prospecting in the area in the 1930s, with the first published accounts of the mining activities described by Junner (1937). Workings extended over a distance of 1.6 km and ore was extracted from both surface and underground workings. The underground workings were accessed by an adit and 10 shafts to depths of 18 m connected by a series of (reef) drives. The 1938/1939 Annual Report of the Gold Coast Department of Mines recorded that the production at Dokrupe for 1938 was 2283 tons from which 4151 fine ounces of gold had been extracted. Presumably mining ceased in the area at the commencement of the Second World War, as occurred at many other mines in Ghana.

A Soviet (former Union of Soviet Socialist Republics) survey team carried out a program of detailed mapping, trenching and drilling on the area in 1962/1963 (Meshcherakov and Yakzhin, 1964). From that work the deposit was estimated to contain a resource of 5 million to 6 million tonnes at 2.6 g/t to 3.5 g/t to a depth of 50 m.

A number of plans and sections of the GCST workings were obtained from the Minerals Commission archives. Those data indicate that GCST commenced prospecting in the area in 1933. Many quartz reefs were examined by means of surface samples, trenches and shafts in the general area of the Dokrupe deposit. Apart from the main line of lode, localised gold mineralisation was identified in the quartz diorite stock 2.5 km to the north of the main deposit. Several lodes were identified at Dokrupe proper within a mineralised zone extending over a strike length of 1.5 km and data obtained on some of these are summarised here.

Strike Length m	Av. Thickness m	Av. grade g/t Au
33.0	1.55	29.3
12.2	0.26	22.5
21.3	1.27	79.7
12.2	1.63	13.5
33.0	0.52	16.0
65.5	0.66	16.0
5.0	0.25	6.8

Source: GCST Limited
Plan Number TS 0850.

Three channel samples 30.5 m apart within the zone of disseminated mineralisation returned the following results.

Length m	Av. grade g/t Au
53.6	2.4
49.4	1.2
21	0.2

Source: GCST Limited Plan Number TS 0882

Geological and Management Services Pty Ltd held the area under a Reconnaissance Licence during 1992/1993. That company carried out a program of regional mapping, VLF-EM geophysics and soil geochemical sampling around Dokrupe. That work was partly responsible for identifying the potential for extensions of the Dokrupe style mineralisation towards Sakpa.

Takoradi exploration

Takoradi has carried out a program of mapping, trenching, soil geochemistry, VLF-EM geophysics and drilling on the Yakomba Prospecting Licence. Most effort has been directed at further defining the mineralisation and resources at Dokrupe, the satellite prospects at Thomas and Senyon and the Sakpa prospect (Figure 4).

Senyon Prospect. Located 3 km north of the Dokrupe workings, the Senyon Prospect was identified initially from evidence of underground workings by GCST in the form of trenches, a number of collapsed shafts and associated mullock heaps. Illegal miners had cleaned out and entered some of the workings. Work by Takoradi included surface mapping, the excavation of a number of trenches and the drilling of nine inclined RC holes.

The surface exploration identified four sub-parallel, steeply inclined reefs striking in an easterly direction and distributed over a zone 200m in width in altered quartz diorite. The reefs vary between 0.5m and 1.5m in width and 60m and 130m in length. Each of the reefs contains gold mineralisation, with the best result being 70.8 g/t Au over 0.4m (cf. tabulation below). Systematic surface sampling of the reefs is not possible because of extensive illicit surface mining and a laterite layer up to 4 m thick.

Reef Analyses — Senyon Prospect

Sample No.	Thickness m	Grade g/t Au
SR1	0.4	70.8
SR2	0.3	17.8
SR3	0.4	15.0

SR4	0.4	15.0
SR5	0.7	27.9

Thin quartz veining in the quartz diorite seen on the mullock heaps indicates the possibility of stockwork mineralisation developed between the main reefs.

The Senyon drilling was designed to test the down-dip extensions and grade of the four reefs in quartz diorite. Holes were also drilled between the reefs to assess the potential for development of stockwork mineralisation. The holes were drilled 20 m apart along a single traverse line to depths of between 11 m and 50 m.

All four reefs were found to persist with depth but three contained generally low gold values, the highest grade being 1.79 g/t Au over 1 m at 23 m in hole Sd. The fourth and northernmost reef was found to be stoped and drilling was suspended pending further investigations of this reef zone. Narrow stockwork zones were intersected between the reefs and, although mineralised, returned only low gold grades

Thomas Prospect. Located half way between the Senyon and Dokrupe Prospects, 1.5 km north of the Dokrupe Prospect, the Thomas Prospect was also identified initially from old GCST workings in the form of a number of trenches and one shaft (Figure 4). Five sub-parallel reefs in quartz diorite distributed over a 200 m wide zone were identified from 15 trenches hand dug by Takoradi. The reefs strike in a northeasterly direction, with the longest strike length being 200 m and the maximum width sampled being 0.56 m. Anomalous but generally low grade mineralisation was encountered in all trenches, with the maximum result being 4.55 g/t Au over 0.39 m. A program of drilling was proposed for that prospect but because of the generally low grades and poor drilling results at Senyon this program has been postponed pending further evaluation of the Senyon results.

Dokrupe Prospect. Surface mapping, trenching and drilling have been carried out over the Dokrupe Prospect (Figure 4). The work has been concentrated over a strike length of 1800 m in the zone, which had been prospected and mined by GCST and subsequently investigated by the Soviet survey team.

A total of 35 trenches were hand dug by Takoradi as part of the investigation program, many of which involved the cleaning and deepening of collapsed 'Soviet' trenches. The objective of the trenching was to confirm the results of the Soviet investigations in terms of the grade and extent of the mineralisation. The trenching results have confirmed the continuous development of a shear zone over the 1.8 km strike length, which contains either solid reef or reef stringers in phyllite and/or quartz diorite. At the northern end, over a strike length of 400 m, there are up to three parallel reef zones. Initial sampling of the trenches indicated the occurrence of mineralised zones up to 5.3 m in width averaging 3.1 g/t Au, but in general the results were lower than suggested from the Soviet data. Despite the limited surface encouragement there was evidence of substantial underground development along the full length of the prospect area and on this basis it was decided that a drilling program was justified.

Drilling was carried out on 19 lines over a strike length of 1786 m. Up to 6 inclined holes were drilled on each line and where more than one hole was drilled on each line the holes were generally 20 m apart. Hole depths were between 20 m and 60 m, with most holes around 40 m. Drill lines were spaced 120 m apart, with some closer-spaced lines in the northern part of the area.

The surface mapping and drilling has shown that the gold mineralisation at Dokrupe occurs in a zone of shearing along the contact between a sequence of phyllites and an elongate intrusion of quartz diorite. Gold mineralisation was found to extend over the entire zone drilled in the form of individual quartz veins, stockworks or a combination of both. The mineralisation occurs both in the phyllite and diorite. In the initial drilling the highest grade individual intersection was 75 g/t Au over 1 m at 54 m in hole 12530B. Broad zones of mineralisation were encountered in several holes, particularly in the southern part of the zone, with the maximum intersection being 2.64 g/t Au over 27 m in hole D1426C (Figure 5). Subsequent resource definition drilling focussed around and to the south of line 1400, where other significant intersections were encountered (such as 28.51 g/t Au over 29 m in hole D1400a). As a result of this drilling a proven and probable reserve of 1.9 Mt was defined with an average grade of 2.54 g/t Au to depth of 75 m.

The mineralisation is open to the south and at depth. There is also potential for additional resources in the footwall and hanging wall, primarily in the southern portion of the zone.

Ongoing exploration. Feasibility studies have shown the reserves at Dokrupe to be inadequate to support a viable stand-alone mine. Takoradi is therefore committed to locating and defining additional resources to the south of Dokrupe and further south into the Waka Waka area. Detailed mapping, soil geochemistry trenching and RC drilling has been carried out on the Sakpa quartz diorite, along with three other prospects referred to as Sambur, Fayam and Sakpa Lombo East Contact (SLEC) (Figure 4). Further drilling has also been carried out at Dokrupe. A total of 63 holes have been drilled for a total of 2654 m. Mineralisation was encountered in each prospect and surface exploration is currently being carried out prior to further drilling. Significant intersections from this drilling are given in the following tabulation.

1997 drilling significant intersections in prospects in the

Yakumba Exploration Licence

Prospect	Drillhole	From m	To m	Thickness m	Grade g/t Au
Dokrupe	DGH1B	10	15	5	6.66
		Incl.13	15	2	9.7
	DGH3	10	36	26	2.52
		Incl.30	32	2	14.37
Sambur	SB3000B	27	36	9	0.67
Fayam	FY6678B	33	41	8	1.95
		Incl.35	36	1	10.38
SLEC	8280B	9	11	2	3.2
SGS	8989A	9	14	5	3.8

Baju Exploration Licence

The western part of the Baju exploration area is underlain by lower Birimian phyllites, which are isoclinally folded and trend in a northerly direction. The phyllites are locally intruded by silicified, fine-grained and foliated biotite granite of the Cape Coast Complex. The eastern portion is underlain by part of a more widely developed complex multiphase granitoid of the Dixcove Complex. In the Baju area two phases are evident, a medium- to coarse-grained hornblende granodiorite and biotite granite. The granodiorite is locally sheared and/or mylonitised with associated chlorite or ?sericite alteration. The shear zones trend in a northerly direction and dip to the west at between 30^{o} and 60^{o}. Auriferous quartz veins are associated with these zones. Simple pegmatite veins with no apparent preferred orientation are widely developed in the hornblende granodiorite and phyllites.

Gold Mineralisation. Auriferous quartz veins known to occur in four of the chlorite/sericite alteration zones within the granodiorite are referred to as the Far East, Badoco, West and Juba Reefs. The Far East Reef is known to extend over a strike length of 2 km and vary in width from a few centimetres to 9 m. The Badoco Reef is located 320 m west of and parallel to the Far East Reef and is traced over a strike length of 800 m. The reef varies between a few centimetres and 3 m in thickness. West Reef is located a further 3 km west of Badoco Reef and is recognisable as a series of lenses over a strike length of about 4 km. The reef strikes in a northerly direction and is best developed at the northern end at Croziers Shaft, where it is up to 3 m thick. The Juba Reef is a newly discovered reef so far known from only one outcrop 1 km northwest of Croziers Shaft. As in the other occurrences the mineralisation occurs in a quartz reef within sheared and chlorite-altered granodiorite.

In outcrop the quartz is milky white and is generally massive, but may be laminated in part. In fresh cuttings the quartz is grey and glassy. Coarse visible gold is often seen in the excavations and gold specks were seen a number of times in drill cuttings. Pyrite, chalcopyrite and galena occur as minor minerals in the veins.

A second type of gold mineralisation has been noted at the southern end of West Reef in an area referred to as the C45 Prospect. In this area gold mineralisation occurs in a swarm of vertical silicified zones in the granodiorite. The veins are generally less than 20 cm thick but may be traced along strike for over 200 m. They strike in an easterly direction and up to five separate veins have been recognised over a zone several hundred metres wide.

Previous exploration and mining

The first reported European observations of gold mineralisation in the Baju area were during reconnaissance traverses by Gold Coast Geological Survey geologists (Teale and Whitelaw 1925; Junner, 1935). In the early 1960s the area was investigated by a Soviet survey team (Nikoulshin et al., 1964) who conducted regional mapping and carried out a heavy mineral pan concentrate stream sediment survey.

There is evidence of shallow strip mining along Far East Reef and Badoco Reef and some shallow underground mining at Croziers on West Reef. There are also remnants of buildings at Croziers and of a crushing and processing plant at Far East Reef. A search of the archives at the Minerals Commission identified a number of geological maps, working plans and sections which indicated that work was carried out by Gold Coast Selection Trust (GCST) during the period 1933 to 1938.

Results from the GCST data included analyses from five strike trenches in the Far Eastern Reef were as follows:

Trench No.	Strike Length m	Av. Thickness m	Av. grade g/t Au
1-1B	30.5	0.17	35.8
11-13	18.3	0.17	26.6
11-13B	41.1	0.22	10.0
13B-14	30.5	0.13	78.3
17B-17C	33.5	0.22	46.4

No production records are available for the GCST mining, although in the Annual Report of the Gold Coast Department of Mines for 1946 there is a report of 482 fine ounces of gold being recovered from cyaniding old sand dumps at Bombirri (Far East Reef).

According to Nikoulshin et al. (1964), evidence of extensive gold mineralisation in other areas to the south and west of Bombirri is indicated by the presence of visible gold in a number of pan concentrates. That observation was confirmed from the data on the GCST maps.

Exploration by Takoradi

Exploration by Takoradi in the Baju area has included mapping, trenching and drilling. As a result of the mapping the old GCST workings were delineated and these were investigated by means of a series of hand-dug trenches. A total of 22 trenches have been completed across the Far East Reef over a strike length of 2 km, with mineralised reef intersected over the entire length. In addition, 11 trenches have been dug on the Far East Reef along a strike length of 900 m and a number of widely spaced trenches have been dug over a strike length of 4 km along the West Reef. Trenches were also dug at the the northern end of West Reef and at an isolated area on the projected southern extension of Far East Reef. A summary of selected analyses from the Far East and Badoco trenches is given in the accompanying table.

On the basis of the trenching results a drilling program was carried out on the Far East, Badoco and West Reef: 42 holes for 1304 m on the Far East Reef: 18 holes for 608 m on the Badoco Reef; and 4 holes for 141 m on the West Reef. In each case the holes were designed to intersect the down-dip extension of reef zones identified from earlier mapping and trenching programs. Each of the reef zones is developed in a band of mylonite in granitic rock dipping in a westerly direction at between 30^{o} and 40^{o}.

As at Dokrupe the holes were spaced on lines 120 m apart and there were generally two holes per line designed to intersect the reef at depths of 20 m and 40 m. Holes were either vertical or inclined at 60^{o} to the east, and ranged in depth between 20 m and 45 m. Some infill lines were also drilled.

At Far East Reef holes were drilled over a strike length of 2040 m. One zone of mineralisation is present in most holes, although two zones were sometimes intersected. The main zone of mineralisation was generally between 1 m and 3 m thick but reached 9 m in one hole. There was a wide variation in gold grade with the best intersection being 12.7 g/t Au over 2 m at 19 m in hole F500SA. Visible gold was observed in six of the holes and potentially economic mineralisation was encountered over a strike length of 1560 m and is open down dip.

At Badoco holes were drilled over a strike length of 720 m, with one main zone being intersected in most holes to a maximum thickness of 2 m. with the best intersection being 5.6 g/t Au over 1 m at 12 m in hole BD 120SA. Potentially economic mineralisation was identified over a strike length of 480 m and is open both to the south and down dip.

At West Reef two lines of two holes each were drilled 50 m apart. They were located down dip from an area of previous mining by GCST at Croziers Shaft. The best intersection was 4.7 g/t Au over 1 m at 28 m in WR2.

A resource of 1 Mt at 4 g/t Au to a depth of 60 m at a grade cut-off of 1 g/t Au is estimated for the areas drilled. There is the potential for additional resources down dip at Far East Reef and both along strike and down dip at Badoco Reef. There are insufficient data to assess the extent of mineralisation at West Reef.
Unlike Dokrupe, much of the mineralisation appears to be associated with surface enrichment. The high grades and coarse gold observed in the trenches do not appear to persist at depth.

Ongoing Exploration. Subsequent to the drilling, further exploration by means of mapping and soil geochemistry has been carried out in the western part of the Baju area. The soil geochemistry has identified a number of linear >200 ppb anomalies associated with biotite granite. These have yet to be investigated further. An isolated outcrop of quartz diorite has also

Trench results, Baju area

Trench No.	Hanging Wall Thickness m	Hanging Wall Grade g/t Au	Reef Thickness m	Reef Grade g/t Au	Footwall Thickness m	Footwall Grade g/t Au
Far East Reef						
1003N	0.90	0.05	1.06	15.60	1.00	0.12**
850N	1.00	<0.10	0.10	0.68**	0.20	1.04
600N	1.10	0.10	1.20	3.49	1.00	0.06
200N	0.47	6.14**	0.76	1.57	1.12	0.25
000N	0.50	0.11	1.07	0.19	1.00	0.28
040S	0.40	8.10				
120S	0.40	0.94	0.20	66.90	0.40	1.92
160S	0.40		0.70		1.00	
200S	0.55	0.46	0.40	37.90	0.74	1.32
240S	0.80	0.36	0.80	5.92		
370S	1.00	<0.01	0.20	0.11	1.00	0.70
497S	1.00	0.74	0.12	56.9	1.00	0.25
592S	0.48	0.83	0.55	10.40	0.40	0.99
828S	1.00	2.11	0.13	34.90**	1.00	0.03
Badoco Reef						
622N	1.00	<0.01	0.27	1.91**	1.70	0.14
206N	1.00	35.00	0.20	4.09	0.70	0.14
000N	0.35		0.36	1.50	1.34	0.07

** Average of two values.
Blanks indicate data are incomplete.

been located and presents a target for further investigation.

Waka Waka Reconnaissance Licence

Outcrop is generally poor in the Waka Waka area but the principal rock types are believed to be metasediments, primarily phyllites, of the lower and middle Birimian. Those rocks are folded isoclinally and strike in a northeasterly direction. Quartz diorite intrusions of the Dixcove Suite are known to occur at several locations, particularly in the north near Sakpa and towards the southwestern border of the Licence. Diorites also occur locally, particularly near the village of Waka Waka in the central part of the area (Figure 4).

Gold Mineralisation. Gold mineralisation is known to occur in the area in association with the quartz diorites but little is known of the nature and extent of this mineralisation. It is presumed to be similar in style to that at Dokrupe.

The Sakpa Reconnaissance Licence Application is nearly square in shape and covers an area of about 650 square kilometres contiguous with the southwestern boundary of the Yakomba Exploration Licence.

Previous exploration and mining. There has been only limited previous exploration and mining in the Waka Waka area. Locally there is evidence of shallow pitting and scraping indicative of small-scale indigenous workings but no hard rock mining has been carried out. The area was included as part of a regional stream sediment pan concentrate survey carried out by a Soviet survey team (Nikoulshin et al., 1964). A number of gold-anomalous areas were identified as part of that study.

Exploration by Takoradi. Initial work by Takoradi has comprised a stream sediment geochemical sampling program covering the entire area. A large anomaly of >50 ppb Au was identified in the southern part of the area and subsequent surface mapping led to the identification of a sheared quartz diorite with quartz stockworks, now referred to as the Cheribong Prospect (Figure 4). A total of 16 RC holes for 766 m were subsequently drilled on the eastern and western contacts of the diorite, the results of which are currently being assessed. The best result was 1.15 g/t Au over 13 m from 18 m in one hole. This mineralisation is open to the south and surface exploration is being carried out prior to further drilling.

A government-sponsored aeromagnetic survey is currently being flown over much of northern Ghana, including the Bole area. A more comprehensive evaluation of the exploration potential of the Waka Waka area is expected when those data are released.

CONCLUSIONS

Takoradi Gold N.L. was set up specifically to operate in Ghana and has been exploring since 1987. During that time the country has gone through a remarkable period of economic revitalisation which has seen a marked improvement in infrastructure and services. Ghana was seen to be a country or great exploration potential and as a result of the rapid changes many more explorers were attracted to the country. Due to lack of initial exploration success, and low initial capital base, Takoradi was not able to capitalise on being early on the ground. Nonetheless the company has persisted and has developed a portfolio of properties with excellent development potential.

For a small company with big ambitions there are two principal lessons from the Takoradi experience:

1. being early on the ground requires a strong capital base; and
2. the window of opportunity will not stay open for very long.

ACKNOWLEDGMENTS

The author gratefully acknowledges the dedication and hard work of Operations Director Brian Sheppard in establishing and maintaining the exploration facilities in the field and Chief Geologist Adamarku Fosu who, with his enthusiasm, depth of knowledge and drive has ensured exploration has continued often through very difficult times. Consultant Geologist Yakubu Idirrisu and his staff carried out the initial mapping and trenching programs at Bole under very trying circumstances and that work is gratefully acknowledged. The contribution of Contract Geologist Simon Meadows Smith is also acknowledged in organising the first drilling programs at Bole and providing a thorough training program for the staff.

REFERENCES

Junner, N.R., 1935. *Annual Report Gold Coast Geological Survey,* for 1934-35, 28pp.

Junner, N.R., 1936. *Annual Report Gold Coast Geological Survey,* for 1935-36, 37pp.

Junner, N.R., 1937. *Annual Report Gold Coast Geological Survey*, for 1936 -37, 11-12.

Junner, N.R., 1940. Geology of the Gold Coast and Western Togoland, with revised geological map, *Gold Coast Geological Survey* ***Bulletin No.11***, 40pp.

Kitson, A.E., 1928. Provisional Geological Map of the Gold Coast and Western Togoland with brief descriptive notes thereon. *Gold Coast Geological Survey* ***Bulletin 2,*** 13pp.

Kitson, A.E. and Teale, E.O., 1918. Geological notes on traverses in the Colony, Ashanti and Togoland. *Report of the Geological Survey* for the year 1916, Accra 31pp.

Kitson, A.E.; Teale, E.O.; Junner, N.R. and Oates, F., 1924. Geological notes on traverses in the Northern Territories. *Gold Coast Geological Survey Annual Report* for 1923-24, 6-39.

Kitson, A.E. and Oates, F., 1927. Geological Notes on Traverses in the Bole, Wa and Lawra Districts. *Geological Survey Annual Report* for 1926-27, 8-34.

Meshcherakov, S. and Yakzhin, A., 1964. Report on the work carried out by revision-estimation party at the gold deposits of Dokrupe and Yoyo. Ghana Geological Survey Department Archive Report No. 60.

Nikoulshin, M.; Bobrov, S.; Meshcherakov, S. and Yakzhin, A., 1964. Geology and mineral resources of the northwestern part of the Kintampo area. (Compiled and edited by I.A. Jakovlev and G.O.Kesse, December 1978). Ghana Geological Survey Department Archive Report No. 54.

Teale, E.O. and Whitelaw, O., 1925. Geological notes on traverses in north west Ashanti and Northern Territories. *Gold Coast Geological Survey Annual Report* for 1923-24, 43-56.