The Discovery, Geology, and Exploration of the High Sulphidation Au-Mineralization System in the Bakan District, North Sulawesi

Penemuan, Geologi, dan Eksplorasi Sistem Mineralisasi Emas Sulfida Tinggi di Kawasan Bakan, Sulawesi Utara

Iip Hardjana

JResources Nusantara

ABSTRACT

The success of Avocet’s North Lanut mine prompted the company to look for similar oxidized, heap leachable, gold deposits. The target deposits should support a dump leach or heap leach operation capable of producing at least 50,000 ounces gold annually over at minimum a 5 year mine life. The Bakan stands out as a prime candidate, as previous exploration identified several silica ledges exhibiting features of high sulphidation alteration and mineralization. The district possesses a number of epithermal high-sulphidation gold occurrences over an area of 3 by 4 km. Gold mineralization in Bakan is hosted by dacitic tuffs of the Plio-Pleistocene Bakan sequence. The tuffs overlie unconformably the Miocene basement units comprising andesitic lavas, feldspathic sandstones and diorite porphyry. Structures that tapped the acid-sulphate fluids are oriented NW to WNW and N-S to NNE. The latter structural trend seems to favour gold mineralization. Hydrothermal alteration is characterized by a core of vuggy silica alteration that grades outward to silica-alunite and alunite-clay. Gold mineralization is mostly within the silicic core (vuggy - massive silicification) of the advanced argillic altered rock.

The project was explored by Newmont, but was not adequately tested by drilling. Avocet, recognizing the untested potential at Bakan, embarked on a program that initially comprised geological mapping, rock sampling, IP survey and trenching. After 8 months of the initial work starting in April 2004, Avocet drilled the best targets in the area and completed its pre-feasibility development program in March 2007. The drilling program at Bakan has demonstrated potential for a small, high-grade gold resource at the Osela prospect and a higher tonnage, lower grade, gold resource in the Durian prospect.

Avocet’s drilling programs comprised 28,636 m in 229 holes and produced Measured and Indicated Resources of 10.32 million tonnes with a grade of 1.07 g/t Au, above the economic cut-off of 0.3 g/t Au for 355,000 ounces of gold (see table below) as well as an Inferred Resource of 6.56 million tonnes with a grade of 0.77 g/t Au, for 163,000 ounces of gold. These resources have been estimated and reported in accordance with the 2004 JORC Code.

Keywords: Au mineralization system, epithermal, high sulphidation, argillic altered rock, Avocet, Bakan, North Sulawesi

SARI

Keberhasilan tambang Avocet Lanut Utara mendorong perusahaan untuk mencari cebakan emas lainnya yang mempelihatkan kesamaan karakter oksidasi dan heap leachable. Deposit yang ditargetkan mendukung kemampuan hasil operasi dump leach atau heach leap, paling tidak 50,000 ounce emas pertahun dalam jangka waktu minimum 5 tahun. Bakan muncul sebagai calon utama, karena eksplorasi terdahulu menemukan sejumlah lapisan tpis-tipis silika yang mempelihatkan fitur alterasi dan mineralisasi yang tinggi. Di kawasan seluas 3X4 km terdapat sejumlah kehadiran emas epithermal sulfida tinggi. Mineralisasi emas di Bakan terdapat dalam tuf dasitis, batupasir felspatik, dan diorit porfir berumur miosen. Struktur yang memberi jalan terhadap fluida asam sulfat berorientasi barat laut sampai barat laut dan utara-selatan sampai utara timur laut. Arah struktur yang terakhir nampaknya mendukung terjadinya mineralisasi emas. Alterasi hidrotermal didikarakteristik oleh al-
INTRODUCTION

Bakan is situated at the southern section of the north arm of Sulawesi (Figure 1). The district lies about 25 km south-southwest of the of Kotamobagu, North Sulawesi, Indonesia. It is within the 6th generation Contract of Work that PT Avocet Bolaang Mongondow (ABM) acquired from Newmont. The ABM, a wholly owned subsidiary of Avocet Mining Plc in London, has exploration and mining rights over the 58,100-hectare tenement.

In late 1980’s, Placer Dome-BHP/Utah Pacific conducted an extensive stream sampling and greenfield exploration over the region on Bolaang Mongondow but withdrew the tenement in 1994. Newmont followed up Placer’s geochemical anomalies within the Bakan District but they were not adequately tested by their drilling program.

Avocet took over the tenement from Newmont in 2002, then drilled the best targets in the area and produced JORC-compliant Measured, Indicated and Inferred Resources for a total of 16.87 million tonnes with an average grade of 0.96 g/t Au (Table 1).

The Bakan mineralization district comprises several silica ledges. These ledges are essentially advanced argillic alteration zones associated with a high sulphidation epithermal system. The alteration system consists of a vuggy silica core, enveloped by silica-alunite, kaolinite-alunite, and illite-smectite assemblages. The silica cores form ridges because of their resistance to weathering and erosion. The gold prospects at Bakan were initially identified through these resistant ridges.

While the geology had been described in several internal reviews by various authors, no compilation has previously been made to document the geological aspects for publication. This paper compiles and describes briefly the discovery, geology, and exploration of the Bakan District from existing unpublished internal reports.

DISCOVERY HISTORY

Bakan was first recognized as a stream sediment anomaly target by the Placer Dome-Aneka Tambang JV in 1989. Streams draining to the north and south of the Bakan ridge shed anomalous gold. Follow-up works; however, by Placer and Antam geologists failed to recognize the importance of vuggy silica and silica-alunite altered floats and decided to leave the prospect area.

Newmont commenced prospect level work to evaluate the potential of the Bakan area in April 1996. After almost a year of work, the Newmont completed base line surveying, stream sediment sampling, rock chip sampling, grid soil sampling, detailed geo-

Kata kunci : sistem mineralisasi Au, epitermal, sulfidasi tinggi, batuan terubah argilik, Avocet, Bakan, Sulawesi Utara.
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Figure 1. Tectonic and terrane map of Sulawesi Island (after Wilson and Moss, 1999, in Umbal et al., 2007).

Table 1 – Combines JORC Resources of Durian and Osela Prospects in Bakan (Umbal et al., 2007)

<table>
<thead>
<tr>
<th></th>
<th>Tonnes (Mt)</th>
<th>Au grade (g/t)</th>
<th>Ounces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured</td>
<td>5.42</td>
<td>1.20</td>
<td>209,000</td>
</tr>
<tr>
<td>Indicated</td>
<td>4.90</td>
<td>0.93</td>
<td>146,000</td>
</tr>
<tr>
<td>Inferred</td>
<td>6.56</td>
<td>0.77</td>
<td>163,000</td>
</tr>
<tr>
<td>Total</td>
<td>16.87</td>
<td>0.96</td>
<td>518,000</td>
</tr>
</tbody>
</table>

logic mapping at 1: 2500 scale, geophysical surveys including ground magnetics, and Induced Polarisation (IP) gradient array. Hand dug trenching and bulldozer costeaneing were also employed to test geochemical and geophysical anomalies.

Newmont applied for a 6th generation Contract of Work under the name of PT Newmont Mongondow Mining and with its approval in 1997, the Newmont resumed activities on the project in August 1997. Further alteration mapping guided by PIMA, trenching and channel sampling, and IP Dipole-dipole were conducted to reassess the drill targets.

Newmont’s exploration works in Bakan were driven by the interpretation that the controlling structures are NE-SW. All the alteration patterns are fitted to the NE-SW orientation. Newmont’s drill program was partly successful as they point to significant gold mineralization in Durian and Osela.

The target generation works led to a second phase exploratory drilling that tested Durian, Jalina, and Osela prospects, completing 6 drill holes aggregating 1,083.0 m by August 1998. One drill hole (BHD-12) at Durian prospect, collared underneath a stretch of channel samples averaging 1.22 g/t Au over 40 m, successfully intersected a hydrothermal breccia body assaying 1.13 g/t Au over 65 m. Likewise, the drilling at Osela (BHD-14 and 15) intersected 7.5 m @ 3.6 g/t Au over 65 m.
Au and 13.0m @ 3.31 g/t Au, respectively. This provided encouragement for the project but not enough to get Newmont to commit further funding on the project. The Newmont withdrew from Bakan and shifted its exploration in North Lanut.

Avocet acquired the tenement in April 2002 and started work in Bakan in April 2004. Avocet’s program in Bakan consisted of two phases, the target generation and the resource definition phases. The target generation phase revealed some new concepts on the mineralization controls. It became evident from the alteration patterns and the elongation of ridges that the orientation of advance argillic zones are essentially controlled by a conjugate set of NNE-SSW and NW-SE fractures (Bautista et al., 2006). The IP survey, done on E-W lines, became more meaningful. Resistive zones were correlated from one line to the next. Durian stood-out as a coherent zone elongated for 600 m on a NNE-SSW direction. Osela becomes clearer and the two Newmont holes (BHD-14 and BHD-15) are interpreted to be on the edge of the zone.

To verify further the interpretation, continuous channel sampling and trenching were conducted. One of the trenches cross-cut the hydrothermal breccia at North Osela and returned an average grade of 4.31 g/t Au over 16 m. Scout drilling was conducted over a number of areas to initially test the different advance argillic zones. The first hole, was drilled in the Camp Breccia prospect to verify the cylindrical breccia pipe. Drilled towards northwest, this hole hit a long stretch of mineralization of 102 m @ 1.63 g/t Au. This revealed that there is a NW-SE control on the emplacement of the hydrothermal breccia (Bautista et al., 2006).

The Main Ridge (ie. Jalina, PDI, Bukit Tengkorak, and Busa) is thought to be an area where both NW-SE and NNE-SSW fractures control the alteration trends. The alterations coalesce to form an area of about 500 m by 1,200 m. Unfortunately, the scout drilling in Main Ridge returned mostly low grade assays over relatively long intervals. Significant intercepts in the Main Ridge are: 44 m @ 0.60 g/t Au, 13 m @ 0.74 g/t Au and 8.2 m @ 1.25 g/t Au, 84 m @ 0.39 g/t Au, 127 m @ 0.39 g/t Au in, 59 m @ 0.61 g/t Au and 15.2 m @ 1.32 g/t Au in the first six holes. Although, the results are not very good, there is still a chance that high grade zones exist within the wide alteration envelopes.

Drill testing in Durian was more straightforward as the IP data shows a coherent resistive anomaly elongated on a NNE-SSW direction. Newmont’s hole BHD-12 also gives confidence that this resistive body is mineralized. Three of the four scout holes drilled in Durian hit quite significant gold grades, to wit:
- Hole BKD020: 50 m @ 1.0 g/t Au from 42 m,
- Hole BKD021: 84 m @ 1.23 g/t Au from 2m, and
- Hole BKD031: 55 m @ 2.35 g/t Au from 6 m.

In Osela, the scout drilling results gave the necessary boost for the project. Testing below the areas with high trench assays revealed high grade drill intersections. They are:
- Hole OSD032: 47 m @ 10.1 g/t Au from surface,
- Hole OSD033: 57 m @ 1.36 g/t Au from 3 m,
- Hole OSD034: 65 m @ 2.49 g/t Au from surface, and
- Hole OSD036: 14 m @ 2.16 g/t Au from 10 m.

The success of the target generation exploration readily justifies the next phase program or resource definition drilling. The resource definition drilling program drilled a total of 28,635.8 m on 229 holes in Durian and Osela. Using the inverse distance method, this work has produced JORC-compliant
Measured, Indicated and Inferred Resources for a total of 16.87 million tonnes with a grade of 0.96 g/t Au, above the economic cut-off of 0.3 g/t Au to contain of about 518,000 ounces gold (Table 1).

GEOLOGICAL SETTING

Regional Geology

The geology of North Sulawesi is dominated by Cenozoic volcanics and associated intrusives, which form a composite island arc (Figure 2). This arc structure is believed to be largely underlain by oceanic crust formed during the opening of the Celebes Sea in the Eocene (van Leeuwen and Muhardjo, 2005) and by thin continental crust at the western part (Carlile et al., 1990).

Three main arc events have been recognized in the North Sulawesi region:

1. Middle Eocene - earliest Miocene, which is characterized by a thick series of dominantly basaltic volcanics of tholeiitic composition associated with deep marine sediments (van Leeuwen and Muhardjo, 2005);
2. Miocene, represented by calc-alkaline volcanics intruded by comagmatic granitoids and interfingering with shallow marine sedimentary rocks and;
3. Pliocene - Recent, consisting largely of sub-aerial volcanics of andesitic-dacitic composition and comagmatic high level intrusions (Carlile et al., 1990; Kavalieris et al., 1992; Pearson and Caira, 1999).

The three arc groups are separated by regional unconformities (Kavalieris et al., 1992) associated with rapid uplifts and pronounced periods volcano-magmatic activities (i.e. and associated mineralization).

Pearson and Caira (1999) showed that the North Sulawesi arc hosts Early Miocene mineralization developed under a regional dextral wrench-tectonic regime and Pliocene mineralization developed under a sinistral

Figure 2. Regional geology of the eastern part of North Sulawesi showing the location of Riska Mine and Bakan Project.
wrench-tectonic regime. NNW arc-normal ESE arc-parallel faults, developed in the Miocene dominates the structural fabric. The intersections of these major fault sets are favoured sites for low-grade Early Miocene porphyry Cu-Au mineralization.

Sinistral reactivation of the major Miocene structures in the Late Miocene and Pliocene led to rifting and ENE-directed dilation. Plio-Pleistocene intrusion and related mineralization exploit these dilatant settings. The later sinistral faulting is a result of an E-W (or WNW-ESE) oriented stress due to the initiation of subduction along the west margin of the Maluku sea. The interplay of these structures proved to be an important component in the mineralization at Bakan (Bautista et al., 2006).

Local Geology

The Bakan District encompasses two magmatic events, those are an older Miocene event characterized by diorite intrusion into andesitic lavas and sedimentary units, and a younger Plio-Pleistocene volcanic event that is responsible for the dacitic pyroclastics and associated acid-sulphate alteration. An unconformity separates the former from the latter.

Stratigraphy

Based on actual field observations, corroborated by regional and district wide correlation, the stratigraphy of Bakan District can be described, from the oldest to the youngest, as follows:

- Middle to Late Miocene rocks, as basement
- Plio-Pleistocene Bakan Sequence
- Pleistocene rock units, and
- Recent deposits

The stratigraphy of Bakan District are presented in Figures 3 and 4.

Middle to Upper Miocene Basement Rocks

These rocks consist of interbedded marine to submarine sedimentary rocks that include sandstone, siltstone, mudstone, graywackes, minor conglomerates, and occasionally lenses of grey muddy limestone. The sedimentary sequences were overlain by and/or interfingeriing with andesitic lava flow.

<table>
<thead>
<tr>
<th>AGE (Million year)</th>
<th>LITHOLOGY</th>
<th>DESCRIPTION</th>
<th>THICKNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recent</td>
<td>Soil and minor tephra</td>
<td>Unconsolidated chaotic breccia, laharic breccia, debris slide, slope rubbles</td>
<td>10-25m</td>
</tr>
<tr>
<td>Pliocene</td>
<td>BAKAN SEQUENCE</td>
<td>Intercalated and intertonguing dacitic ash, crystal, lithic and tuff breccia with coeval porphyritic dacite dome</td>
<td>20m</td>
</tr>
<tr>
<td>Pliocene</td>
<td>BAKAN SEQUENCE</td>
<td>Intercalated lavas, limestone and siltstone</td>
<td>20m</td>
</tr>
<tr>
<td>Miocene</td>
<td>Andesitic lava intertonguing with feldspathic sedimentary rock</td>
<td>Diorite porphyry intrudes the basement units</td>
<td>20m</td>
</tr>
</tbody>
</table>

Figure 3. Bakan stratigraphic column (ABM, 2007).
These rock piles were intruded by fine-to medium-grained diorite, emplaced as stocks and dikes particularly east of Bakan.

**Plio-Pleistocene Bakan Sequence**
Unconformably overlying the basement unit, the Bakan sequence consists of a lower unit of intercalated crystal, vitric, and lithic tuffs with coeval hypabyssal dacite porphyry and an upper unit of consolidated laharic rocks.

The layered Bakan sequence is subaerially to aerially emplaced on a paleo-surface formed by the basement units. Subvolcanic intrusions or small domes of dacite porphries, partially, intrude the basement units and are possibly formed simultaneously with the dacite pyroclastics. During the waning stage of volcanism, hydrothermal fluids must have cause hydro-fracturing and brecciation, forming structurally-controlled hydrothermal breccias. The hydrothermal breccias, like the one in the Camp Site prospect, picked-up rock materials from older formations (even basement rocks) that become clasts in the breccia. The later stage of volcanism is also marked by the reworking and erosion of the dacites to form laharic breccias with dominant dacitic clasts. The Bakan sequence is the most widespread formation in the district.

**Pleistocene rock units**
Continued and renewed volcanism possibly resumed in Pleistocene to early Recent times depositing tuffaceous laharic breccia and debris slide breccias. The tuffaceous laharic breccia is characterized by rounded-subrounded polymict clasts of older rocks set in tuffaceous and/or clayey matrix. Umbal *et al.*, (2007) postulated that this rock unit was probably deposited by debris flow mechanism, relatively distal to source rocks. Debris slide breccia is characterized by very angular to sub rounded monomict or polymict clasts, very poorly sorted, unconsolidated material interpreted to be deposited on slopes proximal to the source.

**Recent Deposits**
The Recent time is characterized by continued uplift of the district with attendant erosion leading to development of raised alluvial gravels, outwash fans, and extensive slope rubbles. Weathering yielded alluvium, fluvial gravels and development of soil horizons.
RESULT AND DISCUSSION

The Middle to Upper Miocene andesites and intercalated sediments were moderately folded probably due to the emplacement of fine- to medium-grained diorite/quartz diorite stocks and dykes. Dips of beds up to 65° were observed along the junction of the east and west fork of the Upper Dumagin River (Purba et al., 1998).

Structures mapped in the district mainly comprise a conjugate set of NW-SE and NNE-SSW, with sub-vertical dips. These structures tapped the acid-rich, hydrothermal fluids that form the advanced argillic alterations. At the Main Ridge area, several NW-SE fractures host vuggy silica alterations that coalesce to form a large alteration zone of about 500 m by 1,200 m. They form resistant silica ridges at Busa, PDI, and Jalina. The Camp Site Breccia also exhibits slight elongation along the NW-SE direction.

The NNE-SSW structures seem to favor a better grade mineralization as demonstrated in Durian and Osela prospects. It is also observed that in Durian, high grade pods occur at the intersection of the conjugate NW-SE and NNE-SSW structures. ENE-WSW structures appear to be late, showing apparent dextral displacement of the Durian ore body. This structural trend also formed graben in the region exemplified by the Bakan and Domoga valleys suggesting that this is a later event.

In Osela, the host NNE-SSW structure bends to the northeast at its northern end. The bend coincides with the high grade occurrence in North Osela reflecting a possible dilatation zone. Chalcedonic veins showing crustiform banding also trend NE-SW and may represent a later mineralization event dominated by near neutral pH fluids.

Alteration in Bakan is dominated by epithermal high sulphidation type alteration mineral assemblages (Figure 5). The high sulphidation alteration assemblages, hosted by a number of structures of different orientation, form zones that coalesce into a large altered area in Bakan, measuring about 2.5 X
3.5km. Acid-rich fluids ascending through fractures progressively reacted with the host rocks and ground water producing a zoned advance argillic alteration pattern. The fluid-wall rock interaction formed structurally controlled vuggy silica core, grading outwards to silica-alunite, kaolinite-alunite, and illite-smectite alteration assemblages. The silica core of this advanced argillic zone hosts disseminated gold and silver in fine-grained silica while at depth, enargite and covellite forms. Bakan is equivalent to the high level alteration features where gold and silver are disseminated within the vuggy silica and silica-alunite alteration assemblage.

In Osela, the presence of banded chalcedonic veins and extremely fine-grained quartz is suggestive of open-space deposition by near neutral pH waters, which is typical of low sulphidation epithermal veins (SKM Report, 2006). These veins are overprinted on a high sulphidation mineralization indicating a later pulse of mineralization that probably caused gold enrichment at Osela.

Evidences of gold enrichment by a supergene process were also observed to be associated with supergene clays, halloysite, and kaolinite, which are weathering products of alunite (SKM, 2006). Gold also occurs in vugs and cavities in association with goethite and limonite indicating a later supergene depositional process.

Some higher grade drill results (> 3 g/t Au), believed to be the products of upflow (i.e. feeder) channels in Durian, exhibit alteration assemblages dominated by vuggy silica or complex mixtures of vuggy silica, alunite, and massive chalcedonic silica. These feeder zones also contain fine-grained pyrite, often altered to limonite within the oxide zone. Interestingly, no Cu-As sulphosalts were observed associated with gold. Some deeper intersections at Durian, Main Ridge, and Camp Site prospects do show enargite and covellite, but the gold content is quite low (<0.1 g/t Au) in these intercepts.

Porphyry style alteration was noted in a very limited area in the district. In a narrow and deep valley, immediately east of the main ridge, a diorite intrusive with magnetite anomaly and weak potassic alteration is exposed (Figure 5). This alteration appears to be limited to the underlying Miocene diorite porphyry and its close proximity to the advanced argillic alteration suggest that this porphyry style alteration maybe unrelated to the Plio-Pleistocene high sulphidation system. PIMA analysis of clay minerals, however, describes dominance of high temperature clay minerals (e.g. pyrophyllites) proximal to the diorite.

Silicified hydrothermal breccias commonly host high grade sections of the ore. These breccias are observed in the Camp Prospect, Durian, and Osela prospects. They consist of angular clasts of silicified rock fragments and vuggy silica in a matrix of chalcedonic silica. The intense alterations of both the clasts and matrix indicate multiple pulses of hydrothermal fluids. The outer margins beyond these alteration zones are characterised by a dominantly propylitic alteration assemblages.

Stream Sediment Sampling

To enable rapid assessment of its CoW’s mineral prospectivity, regional stream sediment sampling and reconnaissance geologic mapping were undertaken by Placer Dome-Utah/BHP-PT Aneka Tambang JV between 1986 to 1989. Multi-element (i.e. Au, Ag, Pb, Zn, and minor Cu) stream sediment geochemical anomalies were identified within the upper reaches of S. Mopopungu, S. To-bayagan and S. Dumagin river systems (i.e. which partially drain the Bakan area), and led to the identification of several argillic-
silica altered areas within the Tobayagan area.

Upon acquisition of the Kotamobagu CoW in 1995 and review of Placer’s data, Newmont expanded the previous regional stream sediment sampling program by targeting smaller tributaries, and thus, further constraining the geochemical anomalous drainages previously identified by the Placer led JV (Figure 6).

Geologic Mapping

Recognition of the “silica ledges” guided Newmont to the potential presence of a high sulphidation deposit in Bakan in the initial evaluation of the area in 1995. Assay results had validated this initial perception, as preliminary rock samples yielded consistent anomalous gold values ranging from 0.10 g/t to 6.72 g/t (Cuffney et al., 1996). Further mapping recognized three Au anomalous zones:

- A more than 5 km-long NE-trending zone (i.e. 0.10 g/t to 3.44 g/t Au);
- A 3 km-long NNE trending zone (i.e. 0.1 g/t to 6.72 g/t Au) with associated vuggy silica alteration; and
- A diffuse NW-trending zone (i.e. 0.2 g/t to 0.88 g/t Au).

Detailed mapping and trenching identified nine potential mineralized sites within Bakan -Jalina, Tengkorak, Main Ridge (i.e. PDI North, PDI South, Busa), Osela, Camp Prospect, Durian and Waterfall sites Figures 5, 7 and Table 2). Complementary results from soil geochemistry and geophysical (i.e. IP and ground magnetic) surveys designated the Jalina, Main Ridge, Camp Prospect, Durian and Osela to be included in the subsequent drilling campaigns.

Soil Geochemistry

Soil samples (i.e. total 1016) collected from the C- horizon by hand auger at depths of one to five meters during the period of April 1996 to February 1997, were analyzed for Au, Ag, Cu, Pb, Zn, Mo, As and Sb. Soil geochemical anomaly patterns with Au values above 38 ppb occur as discrete clusters that correlate well with mapped distribution of “silica ledges” (Figure 7). Four of the largest NW- and NE-trending anomalous zones (i.e. with dimensions greater than 100 m x 150 m) returned Au values above 100 ppb, confined within a roughly continuous 3 km long and 1 km wide east-west trending structural corridor (Purba et al., 1998).

Avocet Exploration Activities

With the acquisition of the Kotamobagu CoW, Avocet proceeded to conduct exploration works in the Bakan area. The main objective is to find bulk-minable and dump-leachable gold deposits containing an aggregate of about 500,000 ounces gold within a 12 km² (i.e. 3 km by 4 km) area.

Results by the middle of 2004 were very encouraging. Alteration mapping and sampling delineated a broad advance argillic zone bounded by NNW-SSE, NNE-SSW and NE-SW faults. Delineated soil geochemical (i.e. Newmont data) and IP (i.e. elevated resistivity and chargeability signatures) anomalies coincided with the projected trend of silica ledges in the Main Ridge area (i.e. PDI North, PDI South, Busa, Tengkorak), and low magnetic signature in Durian (Figure 8). Concurrent trench and rock channel sampling (Figure 9) returned significant assays of 28 m @ 1.01 g/t Au (i.e G. Botak), 23 m @ 1.08 g/t Au (i.e. Busa), 32 m @ 0.77 g/t Au and 15 m @ 1.58 g/t Au (i.e. PDI) and 12 m @ 0.98 g/t Au (i.e. Tengkorak).

Of ten prospects evaluated, six of them—Camp Site Prospect, Main Ridge, Jalina, Waterfalls, Durian, and Osela prospects, proved promising to be included for vali-
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In 2004 scout drilling program. An initial 16 drill targets were identified with a cumulative meterage of 3,500 m. The first ABM hole (BKD018) was drilled on 14 December 2004 using a man-portable diamond drill-rig.

Concurrent with drilling activities, mapping in the Osela prospect identified the presence of large silicified boulders. Twelve trenches were subsequently dug using an excavator exposing advanced argillic alteration halo enveloping two separated NE- and NNE-trending silicified breccia structures referred to as the North and South Osela zones, respectively. Six trench sites returned significant assays of 16.0 m@4.31 g/t Au (BKT38), 14.0 m@3.87 g/t Au (BKT38a), 36.0 m@2.75 g/t Au (BKT42), 10.5m@3.62 g/t Au (BKT47), 5.2 m@41.3 g/t Au (BKT53) and 24.5 m@4.23 g/t Au (BKT57).

Figures 6a and b. Stream sediment sampling points (i.e. BLEG and silt) within the Kotamobagu area as compiled from Placer and Newmont data (Umbal et al., 2007).
Figure 7 – Newmont soil and rock geochemistry in Bakan showing focus area for detailed exploration program 2004/2005 (Modified after Umbal et al., 2007).

Table 2. Highlights of Prospects identified by Newmont within the Bakan Area (Purba et al., 1998)

<table>
<thead>
<tr>
<th>PROSPECT</th>
<th>MINERALISED INTERCEPTS (g/t Au)</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jalina Upper costean</td>
<td>103m @ 0.76</td>
<td>Three narrow (i.e. 2 - 3 m) and laterally persistent (i.e. about 400 m) advance argillic zones (i.e. vuggy silica, alunite-silica and silica-alunite assemblages) within dacite pyroclastics.</td>
</tr>
<tr>
<td>Lower costean</td>
<td>15m @ 1.75</td>
<td></td>
</tr>
<tr>
<td>Main Ridge (i.e. Tengkorak)</td>
<td>12m @ 0.96</td>
<td>Inferred structurally-controlled hydrothermal eruption breccia within an advance argillic (i.e. alunite-silica and silica alunite) alteration halo.</td>
</tr>
<tr>
<td>Gunung Botak</td>
<td>28m @ 1.01 g/t Au</td>
<td>Silica ledge measuring 150 m by 40 m, and elongated to the ENE. Outcrops consist of silicified hydrothermal breccia, vuggy silica, massive silica and silica-alunite altered dacite pyroclastics.</td>
</tr>
<tr>
<td>Main Ridge (i.e. PDI North)</td>
<td>10m @ 0.60</td>
<td>Discontinuous Au mineralisation along the north and south margin of an ENE-trending dacite porphyry dyke with Bakan Volcanic Sequence. Alteration assemblages comprise of spotty silica, alunite-silica and massive to vuggy silica.</td>
</tr>
<tr>
<td></td>
<td>15m @ 1.58</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16m @ 0.36</td>
<td></td>
</tr>
<tr>
<td></td>
<td>17m @ 0.53</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16m @ 0.56</td>
<td></td>
</tr>
<tr>
<td>Main Ridge (i.e. PDI South)</td>
<td>32m @ 0.77</td>
<td>East contact margin of an ENE-trending dacite porphyry dyke with lithic dacite tuff (BVS) characterized by alunitesilica alteration.</td>
</tr>
<tr>
<td>Main Ridge (i.e. Busa)</td>
<td>20m @ 0.64</td>
<td>South contact margin of an ENE trending dacite porphyry dyke with lithic dacite tuff characterized by alunite-silica, massive and granular silica alteration assemblages.</td>
</tr>
<tr>
<td>Osela</td>
<td>44 m @ 1.90</td>
<td>NE-trending sub-parallel, steeply dipping, narrow (i.e. 2 - 4 m) structurally-controlled alunite-silica altered feeder structures hosted in alunite-kaolinite altered dacite lapilli and pumice-rich dacite crystal tuff.</td>
</tr>
<tr>
<td></td>
<td>incl. 22m @ 2.0</td>
<td></td>
</tr>
<tr>
<td>Camp Prospect</td>
<td>Rock chips up to 12.0</td>
<td>A 70 m wide by 250 m long, NNE-trending, steeply dipping, hydrothermal breccia outcrop with silicasulphide and alunite-silica altered sections. Anomaly remains open to the SE and at depth.</td>
</tr>
<tr>
<td>Durian</td>
<td>41m. @ 1.22</td>
<td>Alunite-silica altered, ENE-trending, hydrothermal breccia. Potential satellite extension 150 m to the north of a ENE-trending breccia outcrop returning 22 m @ 0.67g/t Au.</td>
</tr>
<tr>
<td>Waterfall</td>
<td>Rock chips up to 4.15</td>
<td>Narrow (i.e. 4 - 8 m) and laterally persistent (i.e. 500 m) silica-sulphide and alunite-silica altered zone hosted in brecciated dacite lithic tuff proximal to the southern contact margin of a silica-sericite-pyrite altered dacite porphyry.</td>
</tr>
</tbody>
</table>
Figure 8. Outline of IP resistive zones in the Bakan area (left figure). Right figure is a 3-D view of area showing prospect locations in comparison with IP-delineated resistive zones (yellow - orange).

Figure 9. Pre-Avocet rock assay highlights in the Bakan area. Horizontal red bars correspond to limits of IP-delineated resistivity anomaly.
BAKAN RESOURCE ESTIMATE

The geological model for both Durian and Osela (Flindell, 2006) depicts the deposits as “a typical replacement-style, high-sulphidation epithermal system with a core of silicification that grades out through silica-alunite and alunite to clay alteration. Gold also grades out from high-grade feeders to a lower-grade halo. The intensity of alteration and gold mineralization is higher where NE- and NW- striking faults intersect the generally NNE-striking bodies.” The current Bakan resource estimate incorporates assay results and geological data from 106 new drillholes available as of 23rd March 2007 (Milovanovich, et al, 2007). The current model update essentially confirmed the results of the interim June 2006 modelling program, and produced a JORC-compliant Resources for a total of 16.87 million tonnes with a grade of 0.96 g/t Au, above the economic cut-off of 0.3 g/t Au.

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REFERENCES


