EVALUATION OF COPPER DEPOSITS PROSPECT IN WAI WAJO AREA OF SIKKA REGENCY, EAST NUSA TENGGARA PROVINCE

EVALUASI PROSPEK ENDAPAN TEMBAGA DI DAERAH WAIWAJO, KABUPATEN SIKKA, PROVINSI NUSA TENGGARA TIMUR

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ABSTRACT

Lowo Deba prospect in Sikka Regency, East Nusa Tenggara Province shows significant evidences for copper deposit. The prospect is discovered by joint cooperation activity between Directorate of Mineral Resources Inventory (DMRI) and Korea Resources Corporation (KORES) in the systematic exploration program. The evaluation based on the quantitative analysis of rock and mineral characteristics as well as geologic mapping, petrography, mineragraphy, fluid inclusion, spectra analysis (PIMA), geochemical and geophysical data. The geology of the prospect area consists of Miocene volcanics of Kiro Formation and Tanahau Formation, intrusion of granodiorite and Quaternary volcanics. The volcanic rock shows the characteristic of tholeiitic magma. The predominant system of lineaments in the prospect area tends to be NE-SW trend. This fault structure appears to have closely relationship with the mineralization in Lowo Deba prospect.

The mineralization and alteration outcrops appear to be structural controlled to form epithermal deposit type. Most of the mineralizations are hosted by phyllic – argillic altered andesitic to dacitic tuff which is intruded by granodiorite. Rock samples indicate the mineralization type is quartz vein containing chalcopyrite, galena, sphalerite, covellite and pyrite. The best grade revealed from these altered rocks of 6,980 ppm Cu and 50 ppb Au, and from quartz vein of 4,868 ppm Cu and 57 ppb Au. Mineralization stages evolved from initial higher temperatures (> 320° C) to later lower temperatures (near 170° C).

Soil geochemical analysis identify two zones of combined anomaly i.e. Au-Cu-Mo and Ag-Pb-Zn. Those anomalies are concentrated in the phyllic and argillic altered andesitic tuff. These soil anomaly coincide with IP anomalies which are found in electrode separation index of n=5 and n=7 in line WA7 with chargeability value up to 405.7 Msec and resistivity value of 37.7 Ohm-m. In general high chargeability and low resistivity anomalies are developed in the direction of southwest to northeast and still open to the northeast. The high chargeability value allows to predict the occurrence of copper deposits potential. Some bore holes are proposed for the next survey to confirm the presence of new copper deposits in the prospect area.

Keyword : chargebility, copper deposit, Lowo Deba.

ABSTRAK

Daerah prospek Lowo Deba yang terletak di Kabupaten Sikka, Provinsi Nusa Tenggara Timur memperlihatkan tanda-tanda cebakan tembaga. Daerah prospek ini ditemukan dalam kegiatan kerjasama antara Korea Resources Corporation (KORES) dengan Direktorat Inventarisasi Sumber Daya Mineral (DMRI) pada program eksplorasi sistematik. Evaluasi daerah prospek ini berdasarkan pada kuantitas batuan dan karakteristik mineral sebagaimana diperoleh dalam pemetaan geologi, petrografi, mineragrafi, inklusi fluida, analisis spektra (PIMA), data geokimia dan geofisika. Geologi daerah prospek terdiri dari *batuan volkanik Formasi Kiro dan Formasi Tanahhau berumur Miosen, intrusi granodiorit dan batuan volkanik berumur Kuarter. Batuan volkanik memperlihatkan karakteristik magma toleitik. Sistim kelurusan dominan mengarah ke timurlaut-baratdaya. Struktur patahan ini berhubungan erat dengan mineralisasi di daerah prospek Lowo Deba.*

Singkapan mineralisasi dan ubahan tampaknya dikontrol oleh struktur yang membentuk cebakan tipe epithermal. Mineralisasi terdapat dalam batuan tufa andesitik-dasitik dengan ubahan philik-argilik yang diterobos oleh granodiorit. Contoh batuan menunjukkan mineralisasi tipe urat kuarsa yang mengandung kalkopirit, sfalerit, kovelit dan pirit. Kadar terbaik dalam batuan ubahan 6.980 ppm Cu dan 50 ppb Au dan kadar dalam urat kuarsa 4.868 ppm Cu dan 57 ppb Au. Tahap mineralisasi lambat laun terjadi dari temperatur tinggi (>320 ^{o}C) menuju temperatur rendah (mendekati 170 ^{o}C).

Analisis geokimia tanah menghasilkan dua zona gabungan anomali yaitu Au-Cu-Mo dan Ag-Pb-Zn. Anomali ini terpusat dalam tufa andesitik yang terubah philik-argilik. Zona anomali tanah ini berimpit dengan anomali IP yang diperoleh melalui elektroda terpisah dengan indeks n=5 dan n=7 pada lintasan WA7 dengan nilai chargebility 405,7 Msec dan tahanan jenis 37,7 Ohm-m . Secara umum anomali chargebility tinggi dan tahanan jenis rendah berkembang dengan arah baratdaya-timurlaut dan masih terbuka ke arah timurlaut. Nilai chargebility yang tinggi mengarah kepada praduga akan kehadiran potensi cebakan tembaga. Beberapa lubang pemboran disarankan pada survey selanjutnya untuk memastikan ditemukannya cebakan tembaga baru didaerah ini.

Kata kunci : *chargebility, cebakan tembaga, Lowo Deba.*

INTRODUCTION

This paper describe the geology, geochemical and geophysical survey result within Lowo Deba prospect in Sikka District, East Nusa Tenggara Province which indicate significant evidence for copper deposit (Figure 1). The prospect is discovered by joint cooperation activity between Directorate of Mineral Resources Inventory (DMRI) and Korea Resources Corporation (KORES) in the two phases systematic exploration program (2003-2004).

The first phase was regional survey involving geological and geochemical investigations and in order to make out the potential metallic mineral resources in the survey area. The initial survey identified mineral occurrences such as disseminated copper sulphides in Tertiary volcanic rock, granitic intrusion and quartz vein. A reconnaissance stream sediment and float sampling in this area has identified some anomalous copper including gold. The float assay from Lowo Mego revealed of 10 % Cu and 520 ppb Au (Franklin, 1999).

The second phase aims to follow-up of the first phase exploration data and information of copper sulphide occurences by elucidating the geologic setting, relationship between mineralization and geologic structure and mode of mineral deposit type. Geophysical survey has identified geomagnetic anomaly showing NW-SE, N-S, and NE-SW trending similar to the fault structure system. The mineralization is controlled by NE-SW trending fault and the andesite – diorite intrusion filled along this structure. The IP anomaly indicates the mineralization zone of the Lowo Mego still open to the NNE in Lowo Deba (Budi, P., 2000).

Survey of geochemical soil ridge and spurs with 100 m sampling interval and trenching of 50m long with 1 m sampling interval conducted in the middle part of Lowo Deba creek. The results of the survey has identified strong anomalous zones of Cu-Pb-Mn-Mo in phyllic – advanced argillic Tertiary volcanic tuff. Observation from trench shows a good mineralization within silicified andesitic rock. Rock assay revealed 4,980 ppm Cu and 45 ppb Au (Franklin, 2002).

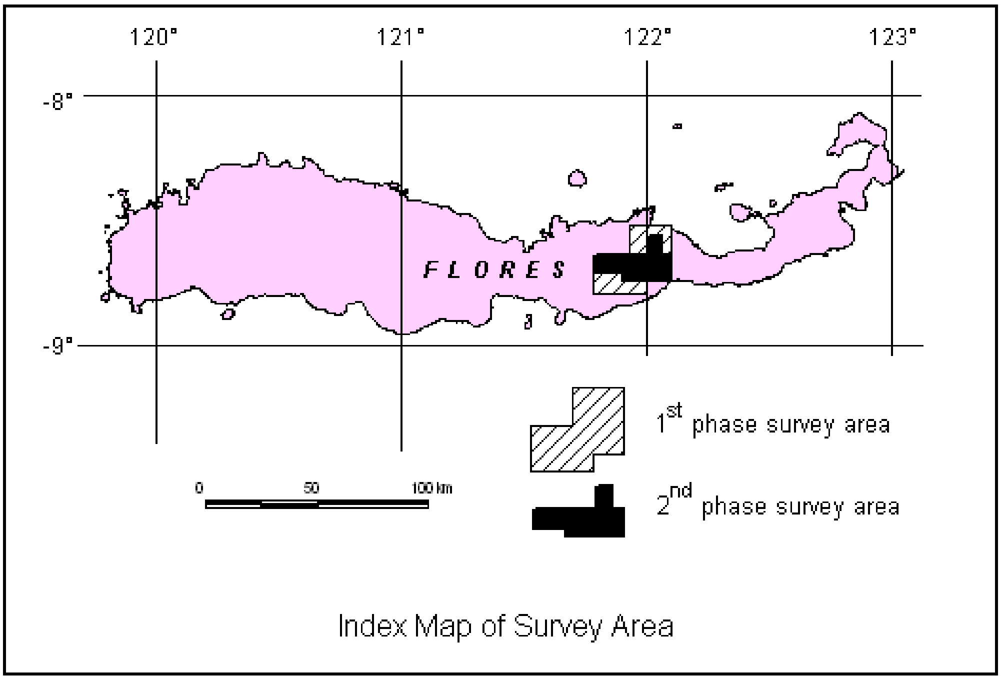


Figure 1. Location of prospect area

The evaluation based on the quantitative of rock and mineral characteristics as well as geology mapping, petrography, mineragraphy, fluid inclusion, spectra analysis (PIMA), geochemical and geophysical data. Hopely this study will let to discover of new deposits in the prospect area.

EXPLORATION RESULTS

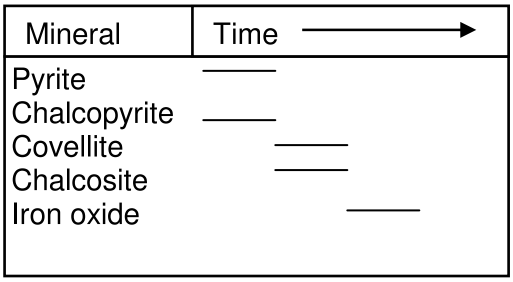
Geological Survey

Based on the surface mapping of the geology, the prospect area consists of Miocene volcanics of Kiro Formation , Tanahau Formation, intrusive of granodiorite and Quaternary volcanics (Figure 2). The name of the formation reffer to regional geology made by Suwarna, et al (1990). The Kiro Formation is characterised by submarine volcanic product consisting andesitic lava, volcanic breccia and andesitic tuff. While Tanahau Formation is composed of lava, breccia and tuff. Lava is rhyolitic in composition and shows pillow structure. Breccia consits of dacite clasts and cemented by silicification of sandy tuff. Tuff is dacitic composition containing silicified and mineralised clasts. From the chemical analysis results of major elements derived from representative volcanics rock in the Wai Wajo area are belong to calc-alkaline and tholeitic series based on Na_2O + K_2O versus SiO_2 diagram as seen in Figure 3. They are also shown in mainly character of tholeitic magma.

The predominant system of lineaments has been interpreted and extracted in the whole survey area tends to be NNW- NNE trend. High-density occurrences of lineaments are found in eastern part of Wai Wajo. Field observation and plotting of joints from the prospect area has been interpreted as two major lateral slip fault systems showing NE-SW and N-S trend (Figure 4) .The NE-SW fault systems is the most dominant in the Lowo Deba prospect area and the mineralization appears to have closely relationship with this fault systems. The occurrences of quartz veins in the survey area is closely related to normal fault, lateral fault and opening as dilation jogs which is affected by both faults (Figure 5).

The mineralization and alteration outcrop appear to be structural controlled to form epithermal deposit type. Most of mineralizations are hosted by phyllic – argillic andesitic to dacitic tuff which are intruded by granodiorite. The alteration minerals were observed by using Portable Infrared Mineral Analyzer (PIMA) application of TSG 2.0 and 3.0 over 213 spectra which consist of illite, halloysite, kaolinite, gypsum, dickite dan paragonite. Gypsum formed in the hydrothermal alteration system is related to the mineral deposit. While dickite is a key mineral for advanced argillic alteration and often found in association with alunite, quartz and in the intenseley acid-leached part of hydrothermal alteration system. Hand specimen sample indicated the mineralization type is quartz-vein containing chalcopyrite, galena, sphalerite, covellite and pyrite (Figure 6). The best grade revealed of 6,980 ppm Cu and 50 ppb Au. The quartz veins are generally hosted by silicified andesitic tuff, altered dacitic lapilli tuff and granodiorite. The best grade revealed of 4868 ppm Cu and 57 ppb Au.

Ore microscopic study from quartz vein indicates cubanite mineral showing lamelar texture (bladed texture) and some times occured as inclusion with sphalerite (Figure 7). The inclusion probably caused by replacement process. In this sample cubanite mineral has replaced sphalerite. Cubanite mineral is the mineralization indicator which is formed in high temperature (>250^{o}C) and generally associated with pyrhotite. From microscopic observation also indicates the presence of secondary minerals such as covellite, chalcocite and iron oxide. Gold was not obeserved due to gold content is extremely low. From ore microscopic study the paragenesis of ore samples can be described as follows:



Fluid inclusions studies were examined in four samples of white to gray milky quartz derived from several quartz veins along the Lowo Deba creek (Table 1). Two types of primary inclusions were recognized in the survey area and classified according to the phases presented at room temperature and their behavior on heating and freezing. Each type is described as follows:

Type I: It consists predominant of liquid , vapor phase and show filling degree between 80 to 90 % volume. Type I inclusions are 10 to 25μm in size and are found in isolated, randomly distributed occurrences and show rounded shape. These inclusions are homogenized to the liquid phase upon heating and contain daughter minerals.

Type II: It is vapor-rich inclusions and show filling degree between 60 to 80 % volume at room temperature. These inclusions occur as primary and show irregular shape. They are usually 5 to 30μm in size. These inclusions are homogenized to the vapor phase upon heating and do not contain daughter minerals. Homogenization temperatures of primary liquid-rich H_2O type fluid inclusions in ore stage, white to milky quartz, from the deposits range from 177° C to 326° C (Figure 8).

The ranges of homogenization temperatures of primary fluid inclusions in quartz related to the ore mineralization are different. Liquid-rich H_2O type inclusions in white to milky quartz related to main ore mineralization homogenized at relatively lower temperatures between 177° C and 284° C than these in barren quartz. Salinity of liquid-rich H_2O type inclusion in ore stage quartz related to ore mineralization range from 3.7 to 12.4 equiv. wt. % NaCl (Figure 9).

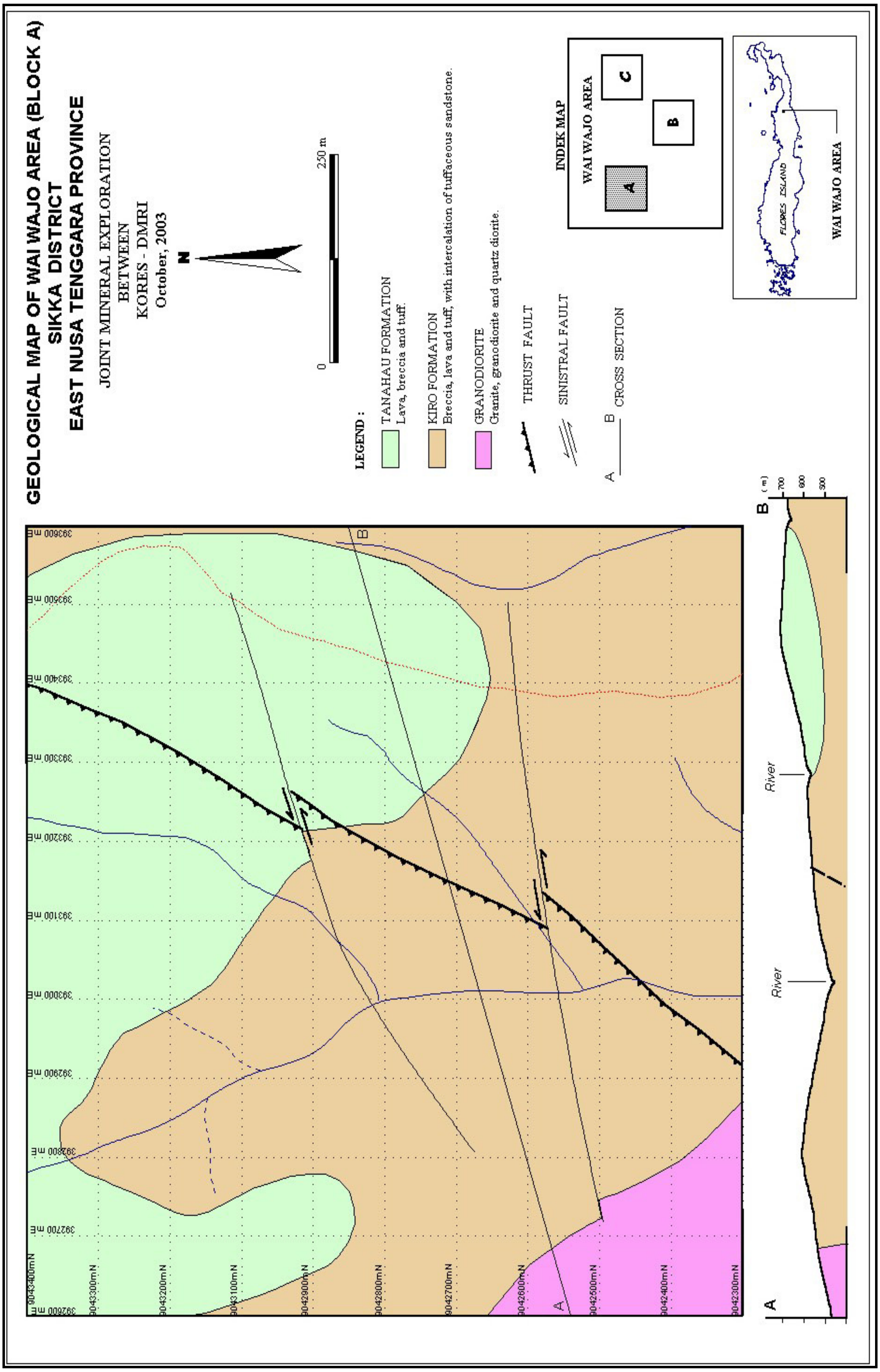


Figure 2. Geological map of Wai Wajo (Lowo Deba prospect).

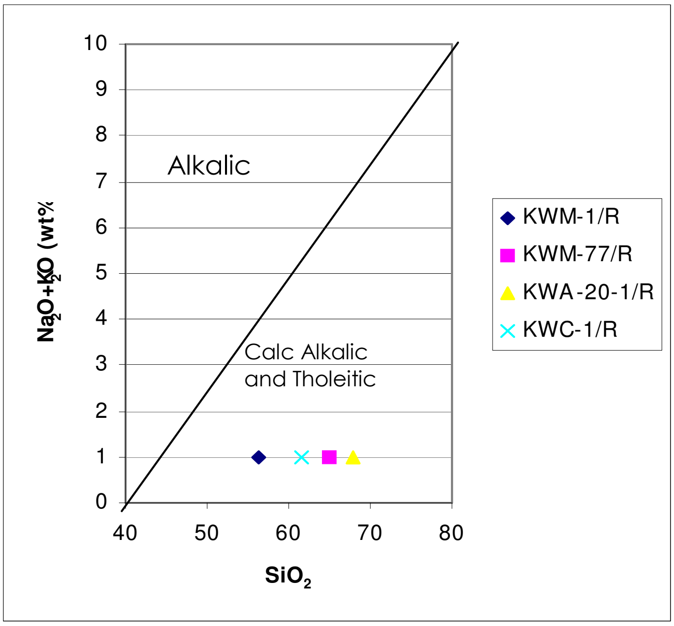


Figure 3. Composition of volcanic rocks from Wai Wajo area in terms of weight percent of silica and total alkalic, calc-alkalic

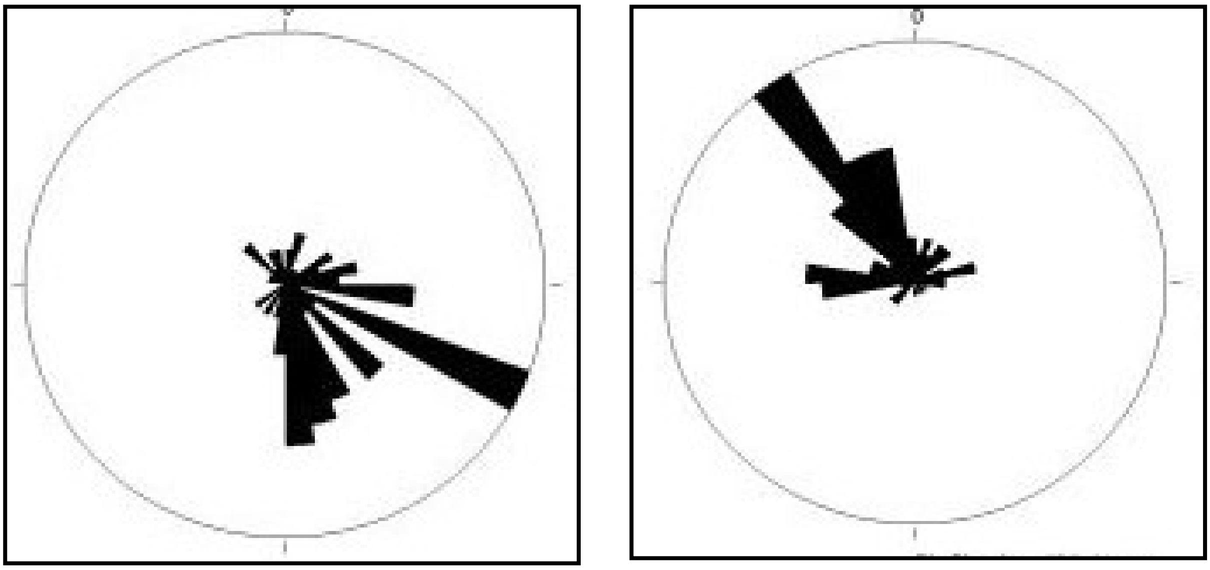


Figure 4. Main direction of joint measurement in Lowo Deba.

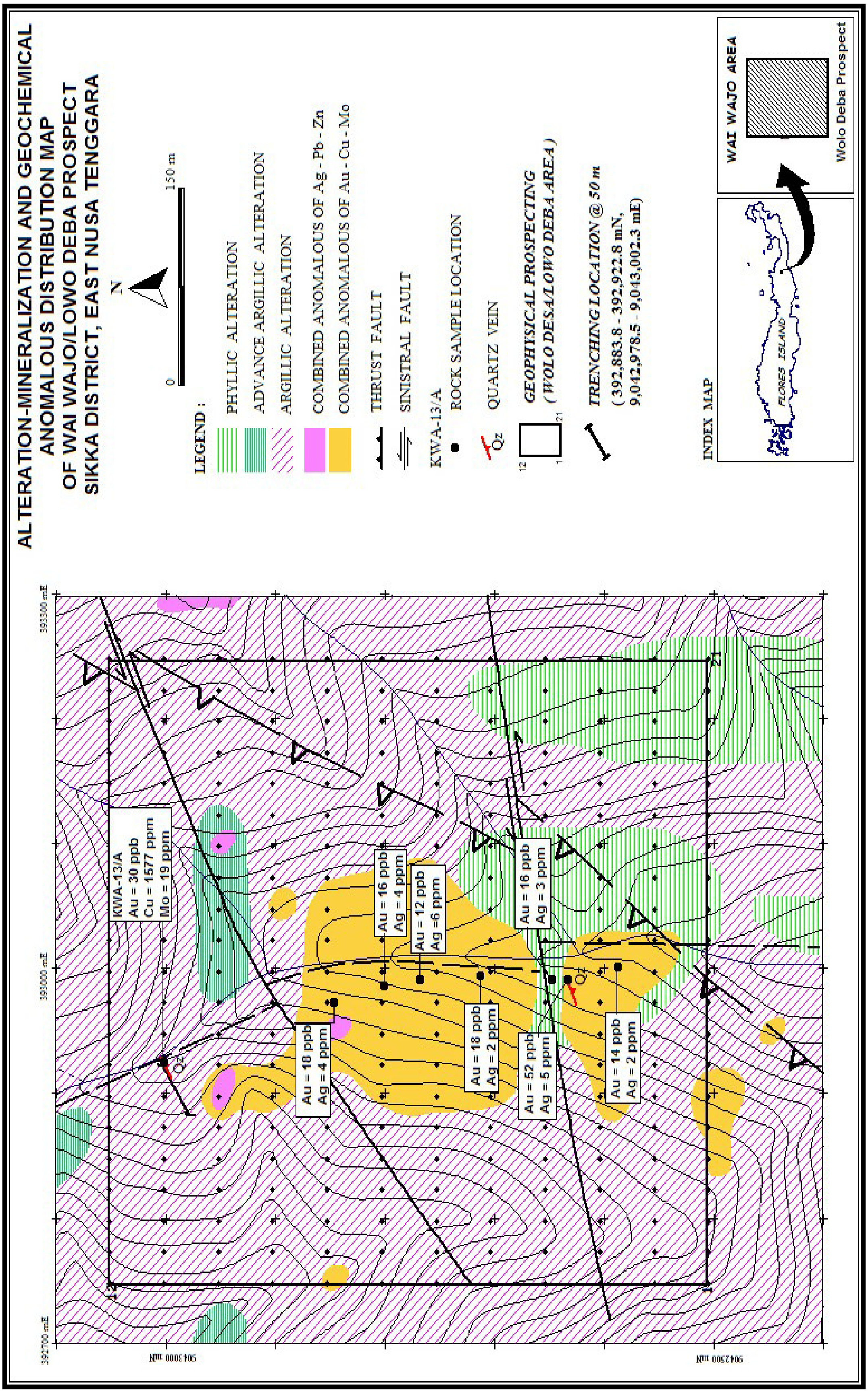


Figure 5. Mineralization-alteration and geochemical anomaly map of Lowo Deba area

Figure 6. Mineralized Quartz vein from Lowo Deba

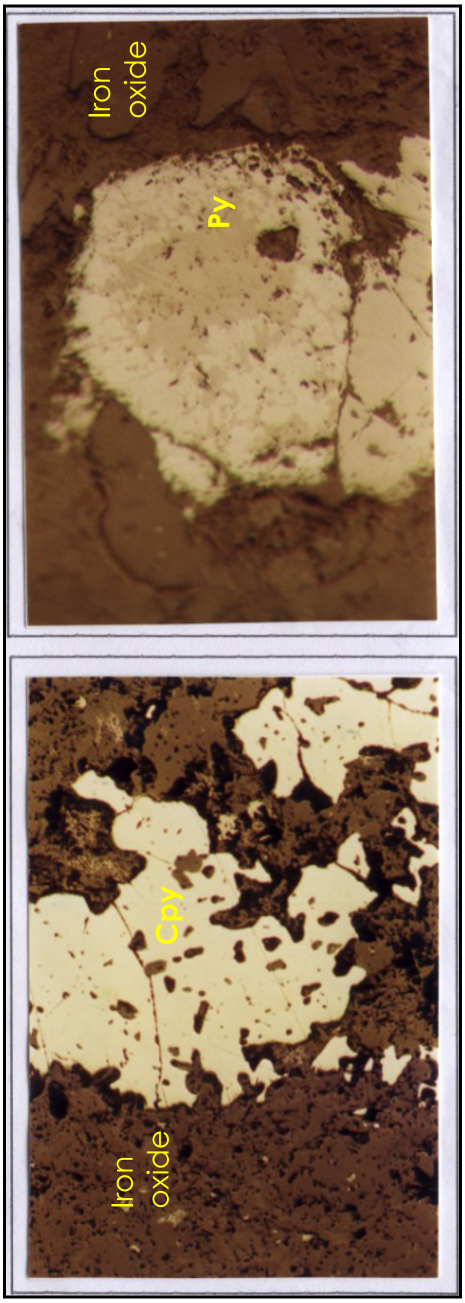


Figure 7. Microphotograph showing pyrite and chalcopyrite(KWA-13/A

Table 1. Mineralogy and fluid inclusion data from Wai Wajo/Lowo Deba

Sample No.	Mineralogy	Host mineral	P.	S.	Th(°C)	Tm(°C)	Eq.wt. % NaCl
KWW-1/RF	Py+gn+sp	gr.quartz	P (30)		201° - 324°	-5.0°-1.0	4.2-10.6
KWW-2/RF	Py+cpy+gn	m.quartz	P (31)		209° - 308°	-0.8°-1.6	3.7-5.0
KWW-3/RF	Py+gn	m.quartz	P (40)		178° - 326°	-6.1°-3.0	7.3-12.4
KWW-4/RF	py+cpy	gr.quartz	P (62)		177° - 320°	-6.0°-1.0	4.1-12.2

Abbreviations: py, pyrite; cpy, chalcopyrite; gn, galena; sp, sphalerite; gr, grey; m, milky; P, primary; S, secondary; eq, equivalent; Th, homogenization temperature; Tm, melting temperature. Numbers in parentheses are the number of inclusions measured.

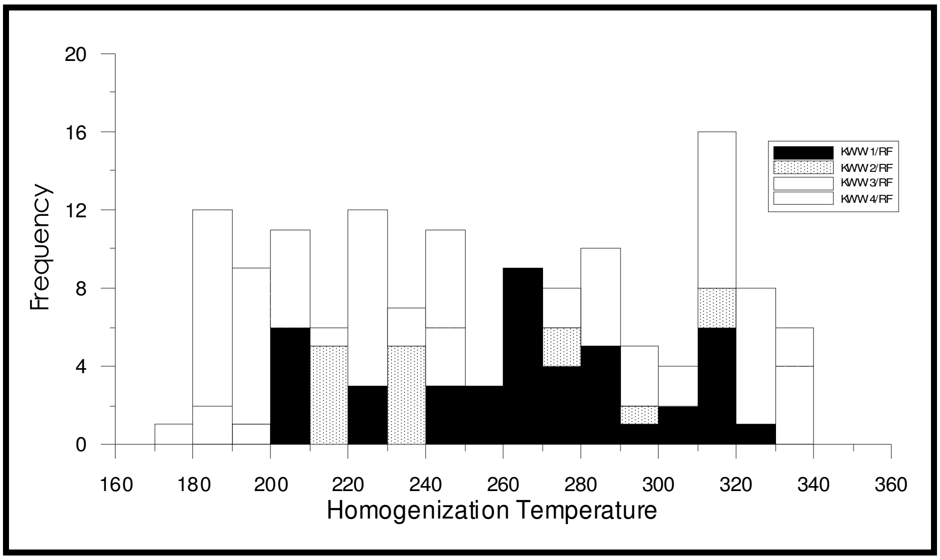


Figure 8. Histograms of homogenization temperatures of fluid inclusions in the main mineralization stage quartz from Wai Wajo area

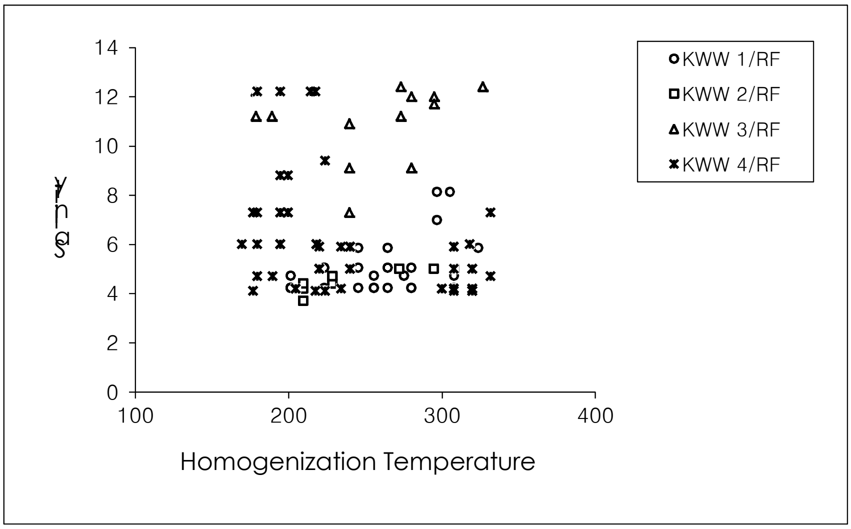


Figure 9. Plots of homogenization temperatures versus salinity for primary Inclusions in the main mineralization stage quartz from Wai Wajo area

Soil Geochemical Survey

Geochemical soil sampling use grid system in area of 1 x 1 km with 50 m interval in Lowo Deba revealed anomalous zones of Cu, Pb, Zn, Au, Ag and Mo elements of various sizes and also identified two general geochemical anomalous zones in which different elements are overlap.

The distribution of anomaly zone can be grouped into two combined anomaly i.e. Au-Cu-Mo and Ag-Pb-Zn. First anomaly is Au-Cu-Mo is distributed in the middle of Lowo Deba prospect and concentrated in the phyllic and argillic andesitic tuff of Kiro Formation. This anomaly area also occupied by base metal and gold mineralization outcrops. The second combined anomaly of Ag – Pb – Zn is distributed in the middle and northeastern part of Lowo Deba concentrated within advanced argillic and argillic dacitic tuff of Tanahau Formation and partly in andesitic tuff of Kiro Formation, showing the similar pattern to first group (Figure 5).

Based on the statistical calculation this element distribution group (Au-Cu-Mo) shows the normal distribution pattern, while the probability plot was inferred to be derived from one population or one-mineralization source (Ahrens, L.H., 1954). While the second combined anomaly of Ag-Pb-Zn from the histogram analysis indicate the normal distribution and from the probability plot is inferred to be derived from difference mineralisation source of the first group (Figure 10).

Geophysical Survey

Geophysical Induces Polarization (IP) survey in Lowo Deba Prospect area is conducted at 12 lines (WA 1-WA 12) with the distance between data points is 25 m and the interval between survey lines is 50 m . Array of IP method was used with dipole-dipole array for five and seven numbers of separation (n=5, n=7) and 25 m of dipole spacing . IP equipment used in this survey is made by IRISH INSTRUMENT Ltd, French. The high chargeability anomaly for n5 spread along the river of east branch and west of Lowo Deba River as showing in figure 11 (c). The chargeability values for n5 have a range of 1.0 ~ 210.0 Msec. There are two high chargeability anomalies in this map. One anomaly lied along the main river of the central prospect area. This anomaly zone is divided by three high chargeability anomalies. The first anomaly is found at the west side of the main river in line WA4 and has high chargeability of 125.5 Msec. Also the second anomaly lay along Lowo Deba River in the central prospect area and has maximum value of 105.0 Msec. The third anomaly is found in northern part of prospect area as the east branch of Lowo Deba River and has a maximum chargeability value of 198.8 Msec.

For n7, there are three high chargeability anomalies zone as seen in figure 11 (d). The first high chargeability anomaly is distributed in the central part of the prospect area along the Lowo Deba River and this anomaly has chargeability values from 20.0 to 420.0 Msec. In general this high chargeability anomaly spread from southwest to northeast and concentrate in the central part of the line WA6, WA7 and WA8 and in the northeastern part of the line WA10, WA11 and WA12. This anomaly still has potential of development toward northeastern part of this prospect area. Three high chargeability anomaly points of line WA4 have the maximum chargeability value of 142.7 Msec. Also second high chargeability anomaly is found in the western part of this area in the line WA8, WA9 and WA10 with chargeability value of 134.3 Msec. The third high chargeability anomaly is found in the west branch of Lowo Deba River in the northern part of this area with chargeability value of 91.0 Msec.

Resistivity anomalies coincide with chargeability anomalies of n5 along the river, east branch and west branch of Lowo Deba River as showing in figure 12 (c). The resistivity anomaly values of n5 have a range of 0.0 ~ 4000.0 Ohm-m. Two resistivity anomalies are related with high chargeability anomalies. First resistivity anomaly is developed along the main river and to locate central part and east branch of Lowo Deba. And this low resistivity anomaly coincides with high chargeability anomalies of composed three spots in this site. In this resistivity anomaly resisvity value is less than 200.0 Ohm-m. The other high resistivity anomaly at the southern part of this map is found in east branch of Lowo Deba River at line WA4 as high resistivity anomaly.

There are three low resistivity anomalies in index n7 on this map as showing figure 12(d). The first low resistivity anomaly is found in the central part of the prospect area along the Lowo Deba River including west branch and east branch. And this anomaly spread from southwest to northeast at line WA6, WA7, WA8, WA10, WA11 and WA12 with resistivity value of 0 – 150.0 Ohm-m. Also this low resistivity anomaly has more potential to develop to the northeastern part of this prospect area. The second low resistivity anomaly is found in the northern part of this area in the west branch of Lowo Deba River and has minimum value of 47.1 Ohm-m. The third low resistivity anomaly is found in the western part of this area in the line of WA8, WA9 and WA10 with minimum value of 42.6 Ohm-m.

DISCUSSION

During the whole survey of the mineral exploration project in Lowo Deba prospect area, documents and information on geology and mineral resources of the prospect area were compiled. While geochemical and geophysical data has been analyzed and interpreted to select the target area for drilling survey.

Base metal mineralization and Ag-Pb-Zn geochemical anomaly zones were identified in Miocene volcanic/ pyroclastic rocks of the survey area. The main anomalous of Au-Cu-Mo is widely distributed in the middle of prospect area. The anomalous zone is occupied by phyllic-argillic andesitic tuff and associated with gold and base metal mineralization outcrops. The alteration minerals consist of illite, halloysite, kaolinite, gypsum, dickite dan paragonite. The mineralisation outcrop found as massive-crystaline quartz- vein containing chalcopyrite, galena, sphalerite, covellite and pyrite.

During the mineralization episodes, variations in temperature and composition of the hydrothermal fluids are recorded by fluid inclusions. The homogenization temperatures of primary inclusions in main stage minerals range from 326° C to 177° C. Each of these stages represents a separate mineralizing system, which cooled and abated prior to the onset of the next. The nearly linear relationship between homogenization temperatures and salinity of fluid inclusions from stages indicates a history of progressive cooling and dilution of ore-forming fluids.

Fluid inclusion study indicate that there is a progressive decrease of average temperature with paragenetic time. Mineralization stages evolved from initial higher temperatures (> 320° C) to later lower temperatures (near 170° C). Therefore, it is probable that Au and base metal mineralization occurred at narrow temperature range of 170° C to 320° C. During the early to main mineralization of ore stage the boiling of hydrothermal fluids led to high but variable salinities. Later cooling and dilution of fluids, which mainly deposited barren quartz in late ore veins in the deposits, resulted in the positive linear relationship between temperature and salinity. The relationship between homogenization temperature and salinities are shown in Figure 9.

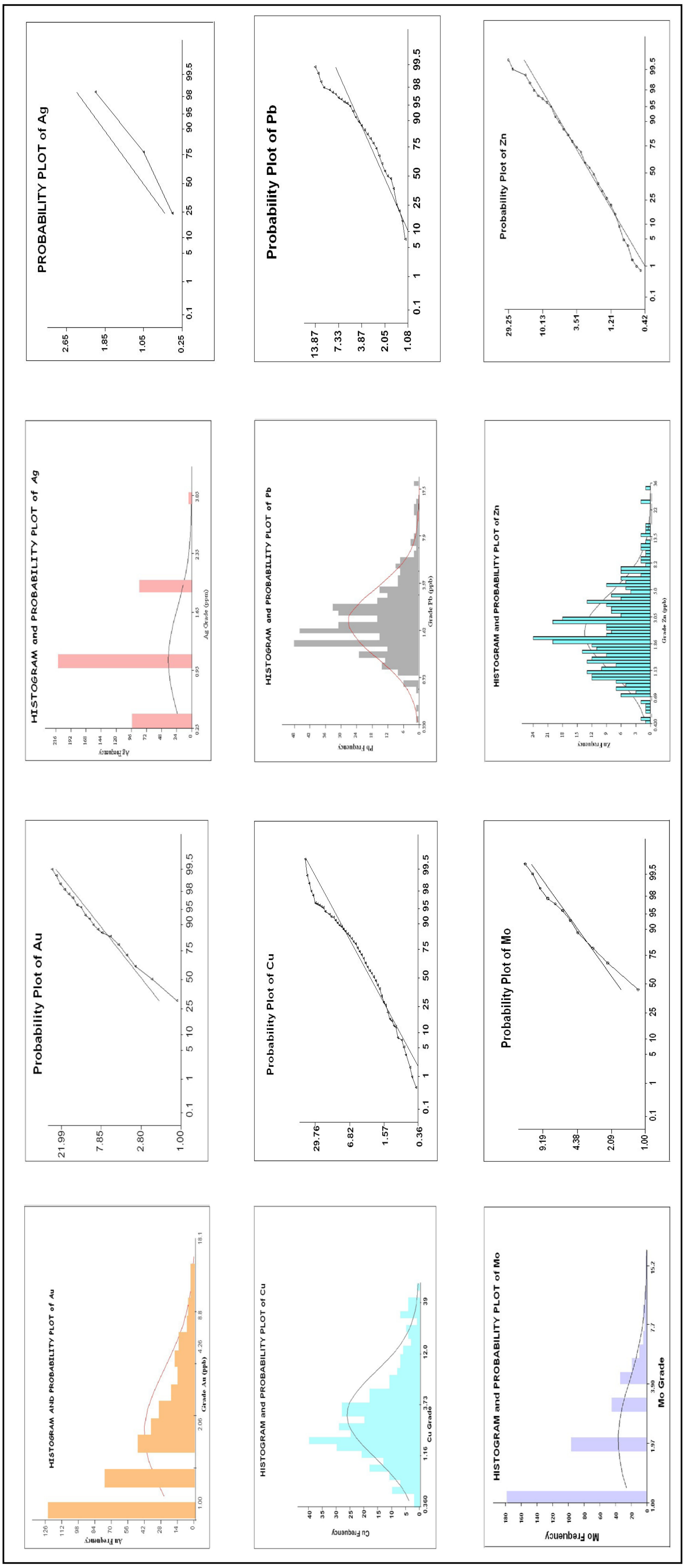


Figure 10. Histogram and log probability plot of geochemical soil in Lowo Deba

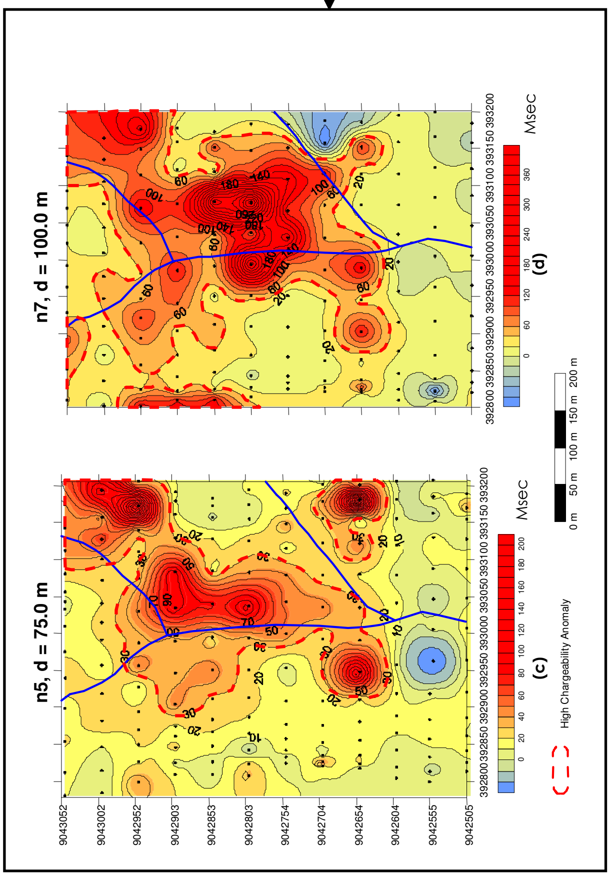


Figure 11. Distribution of chargeability in Lowo Deba Prospect

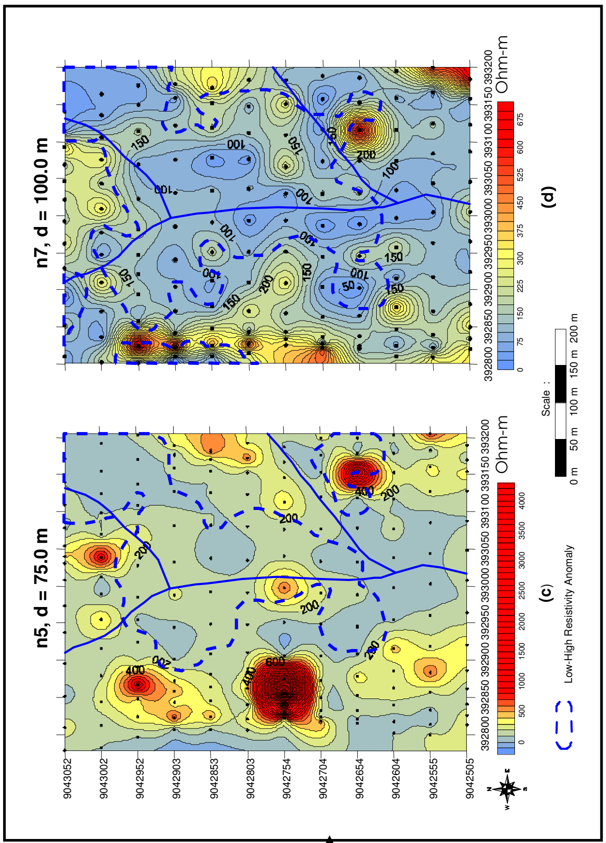


Fig.12. Distribution of resistivity in Lowo Deba Prospect

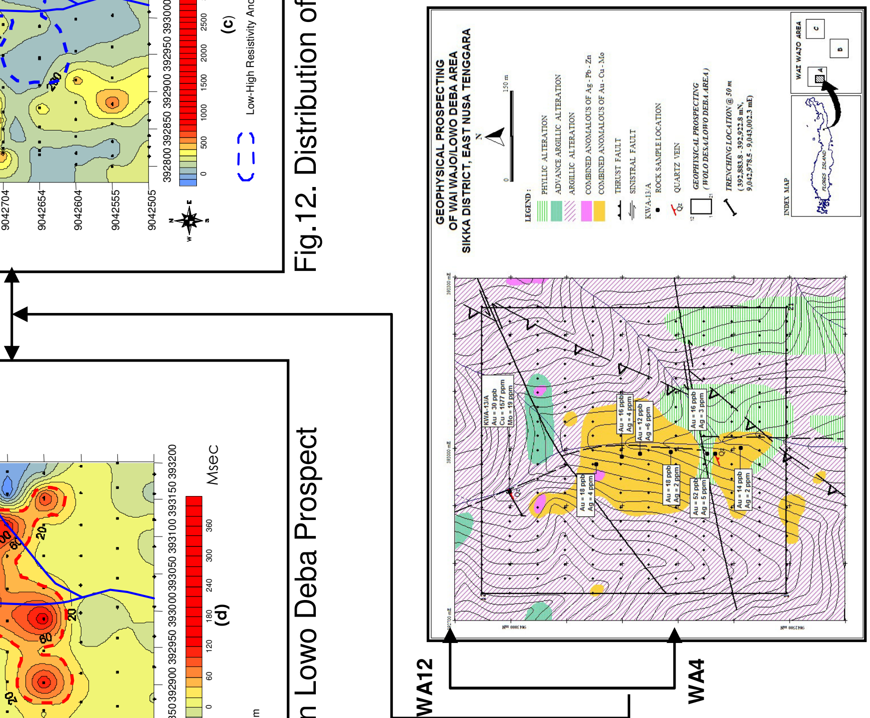


Figure 13. IP Survey at Lowo Deba

From the soil geochemical assay result as seen in Figure 10, the analysis of histogram and log probability indicate two difference mineralization source. The presence of the first group (Au-Cu-Mo) is inferred to be related with the mineralization process forming at high temperature (deep zone). While the appearance of the second group (Ag-Pb-Zn) supposed to be related with mineralization process forming at low temperature. This argument is also supported by study that there are two-inclusion fluid association which represent two temperature of mineralisation forming at low temperature (<200 C) and high temperature (>300 C). The presence of Ag element in the second group is related to low temperature and Mo element in the first group related to high temperature. The presence of cubanite mineral is also indicate that the mineralization formed at high temperature.

The interesting IP anomalies are found from line WA4 to line WA12 in electrode separation index of n=5 and n=7 as represents of illustrated lateral variation of chargeability and resistivity in depth approximately 75.0 m and 100.0 m (Figure 11 and 12). The highest significant chargebility anomaly is found in the centre of the valley of line WA7 with chargeability value of 405.7 MSec and the resistivity anomaly value less than 37.7 Ohm-m. This area is highly recommended to be drilled to find the source IP anomaly (Figure 14). This geophysic anomaly coincide with the soil anomaly.

According to supported data including geology, geochemical and geophysical survey that predict that mineralization type supposed to be epithermal type. In general high chargeability and low resistivity anomalies are developed of direction from southwest to northeast of prospect area and these anomalies still open to the northeast The high chargeability value suggests presenting the potential copper deposits below the surface. Some bore holes will be proposed to confirm the presence of new deposit (Figure 15).

By evaluation of exploration data the mineralisation style in the prospect area is supposed to be epithermal low sulphidation type which is associated with volcanic hosted . On the other hand there is also a significant result from the study of mineral potential mapping for epithermal gold mineralisation using fuzzy logic method in the Island of Flores, East Nusa Tenggara Timur. (Prima, M.H., 2012). The result comprise of a deliniation of new, highly prospective area for epithermal gold mineralisation in the western and eastern part of Flores Island (Figure 16). The Lobo Deba prospect area coincide in the eastern part of study area which is associated with strong stream sediment geochemical anomaly, close proximity to regional-scale faults and alteration zones.

CONCLUSSION

In Lowo Deba prospect area most of the mineralization is hosted by phyllic – argillic altered andesitic to dacitic tuff and granodiorite wich appear to be structural controlled in the form of epithermal low sulphidation vein type. Mineralization stages evolved from initial higher temperatures (> 320° C) to later lower temperatures (near 170° C). The high temperature minerals formed in the deep zone which is related to granodiorite intrusion resulting Au-Cu-Mo group minerals then followed by ascending of hydrothermal fluid into surface at low temperatur resulting Ag-Pb-Zn group minerals.

The geochemical soil anomaly zone coincide with the IP anomaly. The highest significant chargebility anomaly is found in the centre of the valley of line WA7 ranging from 40.0 MSec to 420.0 MSec and the resistivity anomaly value less than 100.0 Ohm-m. This phenomena is led to discover the new deposit by proposed drilling exploration in this area where it is also part of highly prospective area for epithermal gold mineralisation using fuzzy logic method.

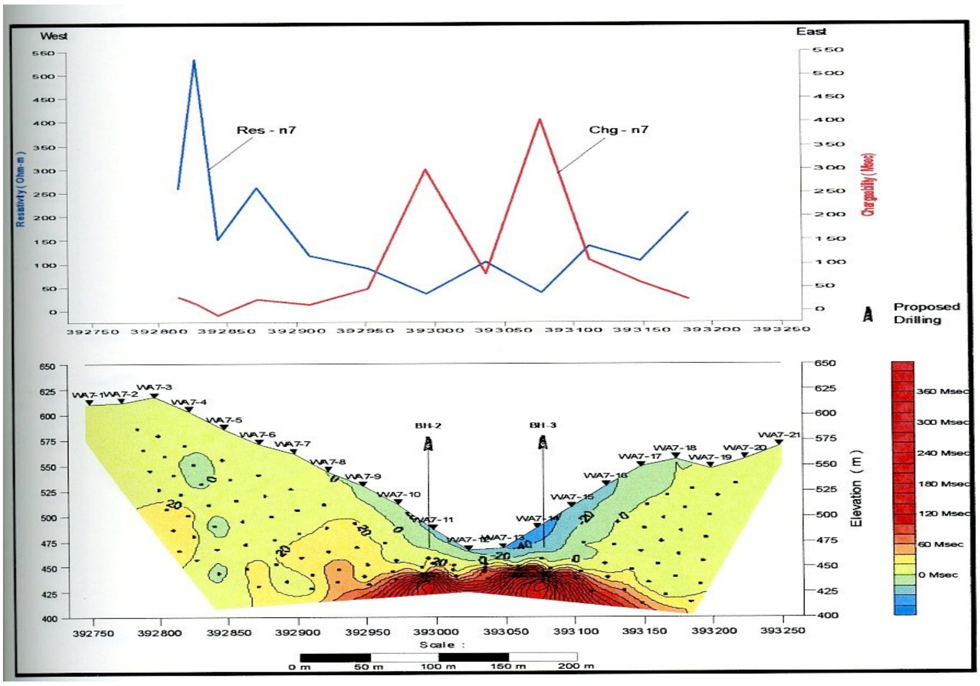


Figure 14. Proposed drilling points in the line WA 7

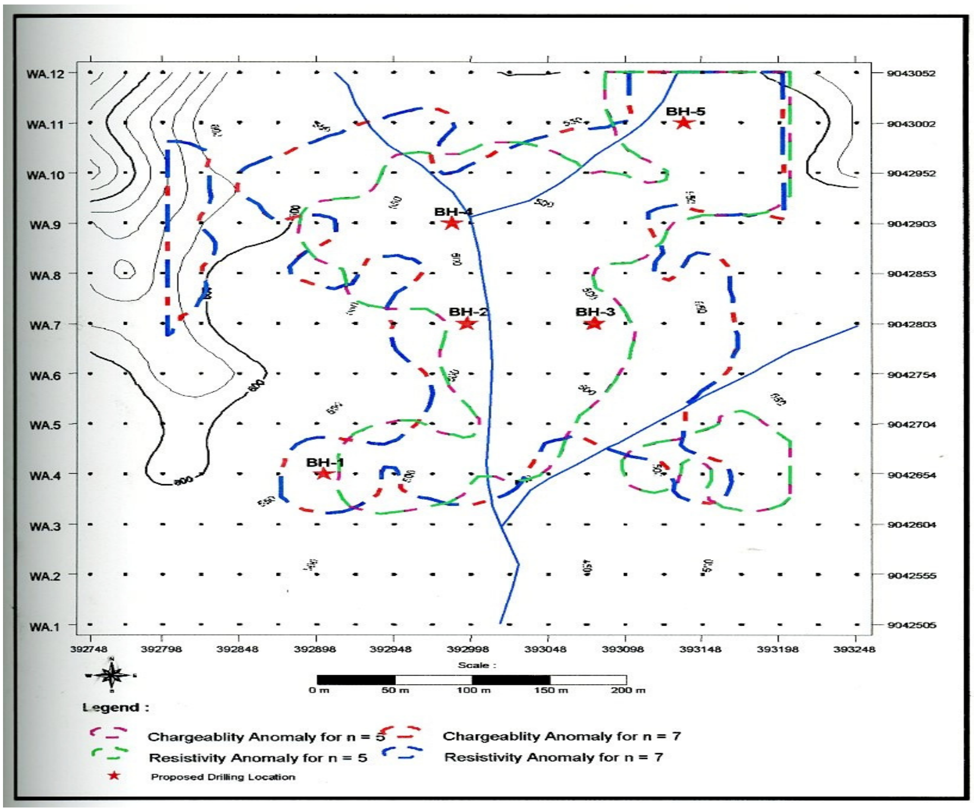


Figure 15. Proposed drill hole location in Lobo Deba Prospect area

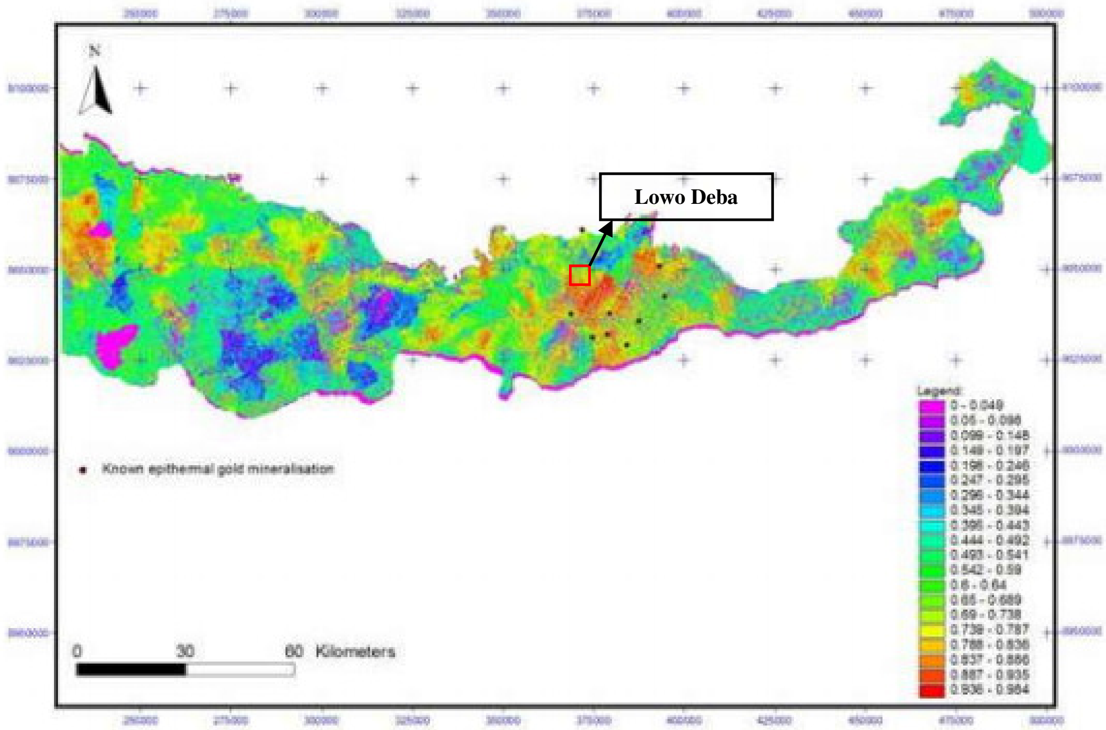


Figure 17. Map of the best potential for gold mineralisation (Prima M.H., 2012)

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