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The Hila Prospect: A Recently Discovered Copper Occurrence on Ambon Island, Republic of Indonesia

by

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Abstract

A potentially important mineral prospect has been discovered in a part of Indonesia with no previously reported mineralization. The Hila Prospect, near Hila village on Ambon Island, contains copper sulfide minerals in 4.4 Ma Ambon volcanic rocks. The host rocks consist of andesite, dacites, breccia and tuff locally intruded by biotite and biotite-cordierite granite. Pyrite- and chalcopyrite-bearing quartz veinlets and hydrothermal breccias in altered, and locally brecciated, andesites crop out over a 1 km distance in one drainage. The altered andesites contain quartz, sericite, disseminated pyrite and locally chalcopyrite. Analyses of four grab samples contain up to 0.014 ppm Au, 530 ppm Zn and 1550 ppm Cu. The geologic setting, alteration, sulfide minerals, and geochemistry all suggest that these outcrops could represent the periphery of a porphyry copper-gold deposit.

Introduction

Anomalous copper and gold values have been obtained from analyses of four samples from the site of sulfide mineralization on Ambon Island near Hila village, Leihitu district, Moluccas Province, in eastern Indonesia (figure 1). There have been no previously reported occurrences of metals from Ambon Island (Sukirno, 1993). The sulfide mineral occurrences were discovered by people from Hila village in 1992 and aroused much local interest. In 1993, Ir. Suparno, of the Indonesian Department of Mines and Energy, went to Ambon to investigate the environmental effects of the local 'mining' activities. The authors visited the prospect in July of 1994 and collected a small suite of samples. This report discusses the general geological setting of the prospect, presents results of the petrographic and chemical analysis of the samples, compares the prospect with existing mineral deposit models, and presents suggestions for further prospecting.

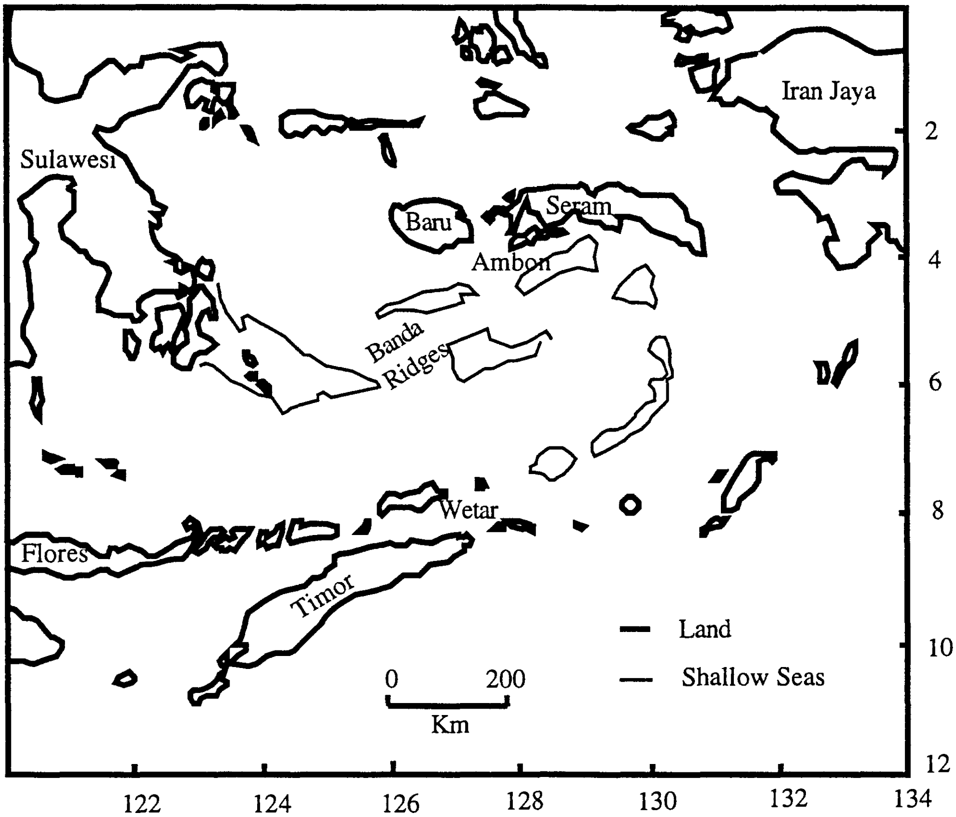

Figure1. Map of eastern Indonesia.

Location

The sulfide mineral occurrences of the Hila prospect are located in the northwest part of Ambon Island about 2.5 km south southeast of Hila village at latitude 3° 36.7' S, longitude 128° 4.5' E (figure 2). Hila village is about 40 km from Ambon City via paved road with a travel time of about 1.5 hours. From Hila village the Hila prospect may be reached by footpaths and stream bed. Travel time from Hila village to the prospects is approximately 1.5 hours.

Physiography

Ambon Island consists of two NE-trending islands connected by a narrow peninsula (figure 2). The larger northern part of the island has a central spine of hills runs the length of the island, reaching a maximum elevation of 1038 meters. The elevation of hills along the central spine about 5 km south southwest of Hila Village is 891 meters. The island is characterized topographically by steep terrain. Streams draining to the north of the central spine of hills are generally shorter than streams draining to the south of the spine. The longest streams are 8 km long; streams as short as 2 to 3 km are common. The streams are straight throughout their course. They are narrow (1 to 3 meters wide), shallow (10 to 20 cm. deep), and occur in deeply incised valleys (10 to 20 meters wide and 5 to 10 meters deep) in their upper reaches. Small waterfalls are present in the upper reaches of the streams. In their lower reaches the streams are 4 to 10 meters wide, .5 to 1.5 meters deep, and fast flowing (figure 3). Streams carry abundant detritus. Weathering near the prospect reflects the wet tropical climate. Outcrops are confined to the sides of deeply incised streams. The hills near Hila village are covered by dense tropical forest that provide hardwoods, cloves, bananas, jerux bali (a citrus), chocolate, and kenari nuts.

Geologic Setting

Ambon Island is located at the margin of three large lithospheric plates, the Australian, Southeast Asian, and Southwest Pacific, and its geology records their complex interaction. Ambon, and the nearby islands of Seram and Baru (figure 1), represent slivers of continental crust that were faulted off of New Guinea. Paleomagnetic data indicate these slivers have moved westward and northward during, and perhaps preceding, Miocene time (Linthout and Helmers, 1994).

Although the island has a complex history, the stratigraphy of Ambon, as reported by Tjokrosapoetro and others (1994) is relatively simple. The oldest exposed rocks are part of the Kanikeh Formation of Triassic to Jurassic age (figure 2). Lithologically this formation consists of interbedded sandstone, shale, siltstone, with intercalations of conglomerate and limestone. The detrital sediments include arkose and graywacke.

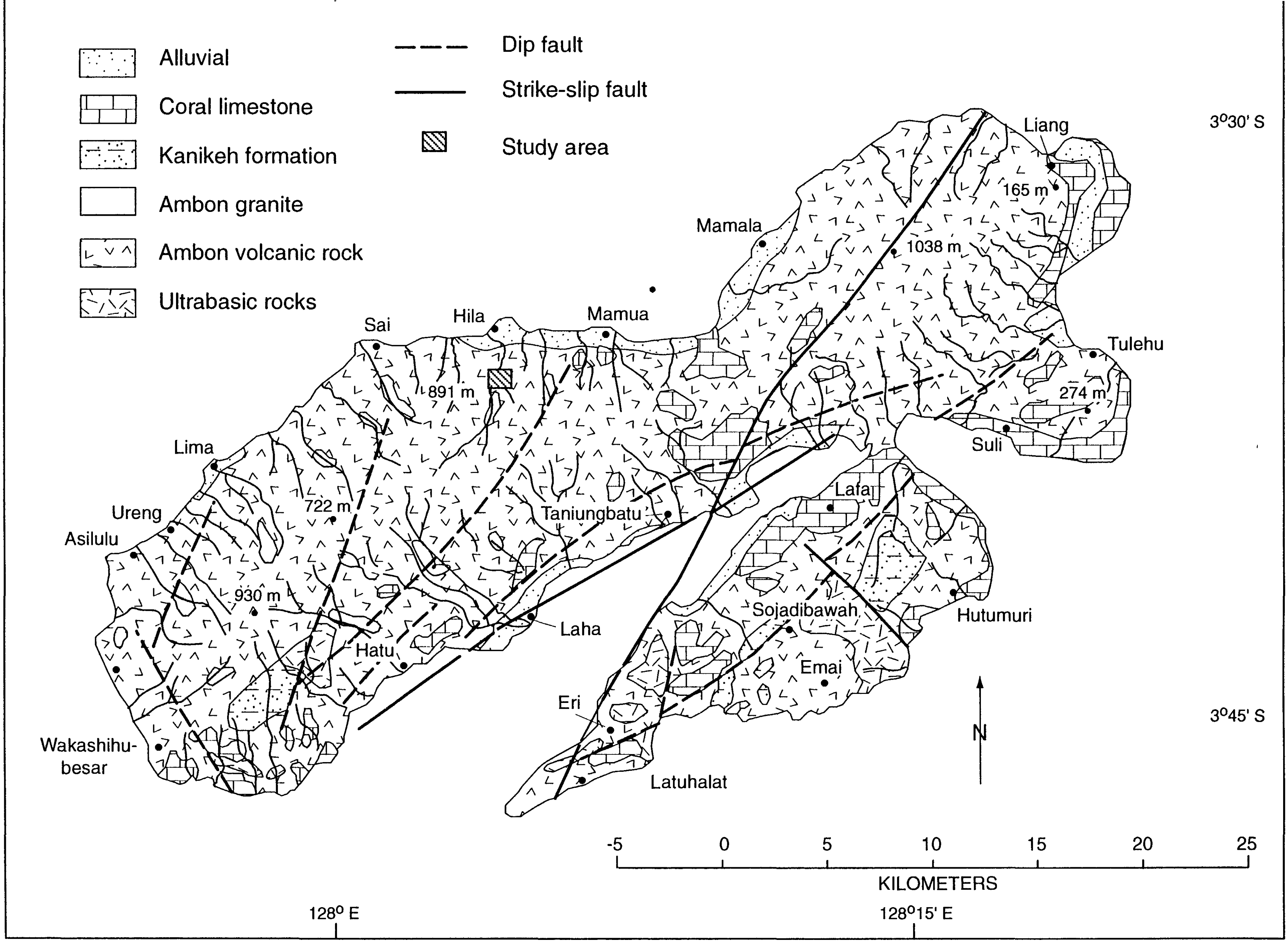

Figure 2. Geologic map of Ambon (modified from Tjokrosapoetro and others, 1994).

Figure 3. View of the lower reaches of the stream draining the Hila prospect.

The next youngest rocks are ultrabasic rocks of Jurassic and Cretaceous age. Lithologically this unit contains harzburgite, dunite, serpentinite, and gabbro (Tjokrosapoetro and others, 1994). The relation of the ultrabasics to the Kanikeh Formation is not clearly indicated on Ambon, but on Seram, Tjokrosapoetro and others (1994) show it to be a structural contact, with the ultrabasics thrust over the Kanikeh Formation. Linthout and Helmers (1994) suggest that the ultramafics represent oceanic crust formed in a passive margin about 14.5 Ma ago. They believe the oceanic crust was obducted onto Ambon, Baru and Seram Islands before 4.4 Ma ago, at which time the Ambon volcanic rocks were erupted.

The Ambon volcanic rocks are composed of andesite, dacite, breccia, and tuff. K/Ar geochronology of the Ambon volcanic rocks has yielded dates of 3.4 to 4.4 Ma (Abbott and Chamalaun, 1981). The volcanic rocks are intruded by the Ambon Granite which consists of biotite granite and biotite cordierite granite. While the Ambon volcanic rocks are widely distributed across the island, the Ambon Granite only crops out in the western half of the northern peninsula (figure 2). The outcrops of Ambon Granite occur within an area about 20 kms long and 10 kms wide, and have a crude radial pattern, reflecting the distribution of the stream drainages.

Silver and others (1985) suggest that the Ambon volcanic rocks and intrusive rocks were formed as the result of thrusting of continental slivers beneath the Banda ridges (figure 1). Alternatively, Linthout and Helmers (1994) suggest that the volcanic rocks and intrusive rocks are the result of mixing magma derived from partial melting of pelitic rocks due to obduction of the oceanic crust, with basaltic/andesitic magmas emplaced along transform faults. They believe the transform faults had left lateral movement and were the mechanism for moving Ambon, Baru and Seram Islands north and westward in a counter-clockwise rotation. The pattern of the faults shown on the geologic map of Ambon (figure 2) is consistent with left lateral movement.

Quaternary coral limestone crops out at many places on the island. The occurrence of Quaternary limestones at elevations up to 500 meters above sea level attests to the rapidity of recent uplift on Ambon Island. The youngest unit on the island is Quaternary alluvium which on Ambon is principally beach material.

Sulfide Mineral Occurrences Near Hila Village

The sulfide minerals near Hila village occur in veinlets and stockworks in Ambon andesites. Pyrite and chalcopyrite are the principal sulfide minerals observed, and the principal gangue is quartz. Grab samples of mineralized rock may contain up to 15 percent sulfide minerals. Mineralized rock was observed in two adjacent drainages, and crops out over a distance of at least 1 kilometer in one drainage (figure 2). The andesites that host the mineralization are brecciated (figure 4) and pervasively altered over the same interval. The mineralization must be Pliocene or younger.

Petrography of Selected Grab Samples

The following descriptions are based on hand specimen, and thin or polished sections of a suite of fist sized, grab samples of the types of rocks we observed during a one day (July 3, 1994) visit to the Hila prospect. Sizes and percentages are visual estimates rather than the results of systematic point counts. These samples are not necessarily representative of the proportions of the rocks present at the prospect.

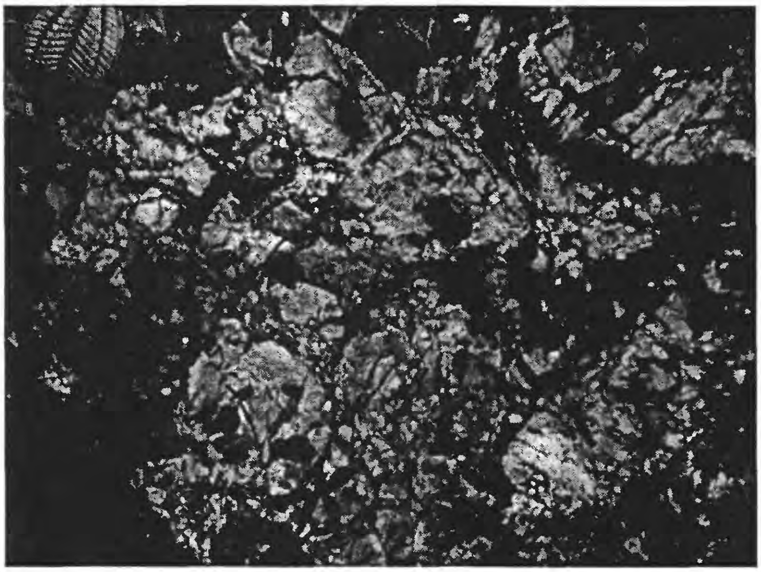

Figure 4. Brecciated and altered rocks from the Hila prospect.

Sample: Ambon 1

This sample is a light gray, altered, porphyritic volcanic rock. In hand specimen the rock contains small, rounded feldspar phenocrysts set in a very fine-grained groundmass that contains disseminated pyrite and numerous small (1 - 5 mm diameter) vugs. Where weathered, the rock is white with rusty iron staining.

In thin section, phenocrysts are 1 to 3 mm diameter, milky white, feldspar laths. The phenocrysts are set in a light-gray fine-grained groundmass composed of quartz, sericite, and minor chlorite. Groundmass quartz is very fine-grained (about 0.07 mm.). Pyrite constitutes between one-half and two percent of the rock. The pyrite occurs in three sites - disseminated in the groundmass, in altered feldspar phenocrysts, and filling vugs. The vugs in the thin section are 0.2 - 2.0 mm in diameter and are filled with drusy quartz and pyrite. Quartz and pyrite appear to have been deposited essentially comtemporaneously with some quartz preceeding pyrite. The drusy quartz crystals contain very small primary and pseudosecondary fluid inclusions. The inclusions appear to contain 2 phases - a liquid and gas phase, and are too small (approximately 1 micron in diameter) to be analyzed by normal methods of studying fluid inclusions.

Sample: Ambon 2

The sample is a light green-gray, fine grained volcanic rock with disseminated pyrite. Weathered surfaces contain abundant iron staining. In polished section, small (3 to 5 mm. in diameter), pale green, lithic fragments can be seen in a light-gray, fine-grained groundmass. The groundmass predominates over the lithics and exhibits a well-developed flow texture that is defined by microlaths of feldspar. The lithic fragments represent local autobrecciation of the volcanic rock. The groundmass and lithic fragments have been pervasively altered to quartz and sericite. The sample also contains sparse feldspar phenocrysts (1 - 3 mm diameter). About 2 - 7 percent of the sample is composed of pyrite; chalcopyrite was observed in trace amounts. The sulfides replace lithics, are disseminated in the altered groundmass, and occur as 2 - 3 mm diameter blebs along microfractures 0.1 - 0.5 mm wide. Chalcopyrite occurs as rims on pyrite. Hydrothermal quartz contains primary or psuedosecondary, two phase liquid and vapor fluid inclusions that range in size up to about 15 microns.

Sample: Ambon 3

This is a light gray to white, fine grained, altered and bleached volcanic rock with a stockwork of thin pyrite-bearing veinlets and iron staining on weathered surfaces. In polished section, small (1 - 3 mm diameter) milky white feldspar phenocrysts in a light tan groundmass are observed. The groundmass has been pervasively altered to quartz and sericite. Small (1 mm. diameter) cubes of pyrite are disseminated throughout the groundmass. Two sets of quartz veins cut the rock. The earliest set of veins are thin (about .1 mm thick) and are mainly quartz with rare fine-grained pyrite cubes. The later set of veins are 1 - 5 mm thick, form a stockwork, and contain quartz, pyrite, and rare chalcopyrite. Early quartz along the margin of these veins is fine grained. Later quartz in the interior of the veins is larger and has well developed crystal forms. Sulfides constitute 20 to 40 percent of the vein. Veins constitute about 20 percent of the sample.

Sample: Ambon 4

This is a medium gray-green breccia composed of light green gray, angular fragments of volcanic rock having a dark green-gray matrix with abundant chalcopyrite and pyrite. In polished section, the hydrothermal character of the breccia becomes apparent. The breccia fragments are 0.3 - 2 cm in diameter and are replaced by masses of chalcopyrite and pyrite, and quartz. The breccia contains fragments that vary in size from 0.3 to 1.2 cm in diameter, and have flow textures similar to those observed in sample Ambon 2. They have been pervasively altered to quartz and sericite. Sulfides, which comprise 40 - 50 percent of the sample, occur in thin (0.1 - 0.2 mm) microfractures, disseminated in lithic fragments, and large masses between the lithic fragments (figure 5). Quartz is best observed in transmitted light (figure 6) where it can be seen in microfractures and as fine grained rims around lithic fragments and as drusy crystals that fill open space adjacent to the fragments. Breccia fragments are cut by two generations of quartz veins, both of which contain sulfide minerals. The later veins are related to infilling of the breccia. Sulfides encase well formed drusy quartz crystals. The matrix is fine-grained rock flour that has been partially cemented with quartz. Drusy quartz crystals contain large (12 - 13 micron) primary fluid inclusions that contain two (vapor and liquid) and three (solid, vapor and liquid) phases. The three phase inclusions are hypersaline containing an estimated 35 to 40 percent (volume) salt. The quartz also contains smaller (2 - 6 micron) pseudosecondary inclusions that occur along fracture planes in the quartz.

Geochemistry of samples from the Hila prospect

Selected grab samples from the Hila prospect were chemically analyzed to characterize the mineralization. Samples were prepared for analysis by crushing in a jaw crusher, followed by grinding using a rotary grinder with ceramic plates. The resulting material was split and a portion submitted for analysis. One sulfide-rich sample (Ambon 4) was diluted by a 10:1 ratio prior to analysis. Data in table 1 have been adjusted to reflect this dilution. Gold was measured using atomic absorption graphite furnace analysis. The elements Ag, As, Bi, Cd, Cu, Mo, Pb, Sb, and Zn were analyzed using ICP atomic emission spectroscopy. Results of the analyses are in Table 1.

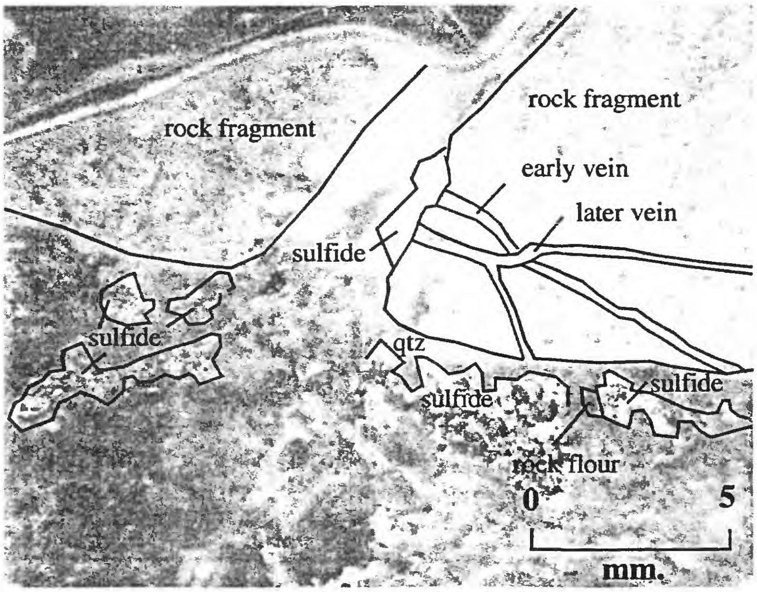

Figure 4. Photomicrograph of hydrothermal breccia (Ambon 4) in reflected light.

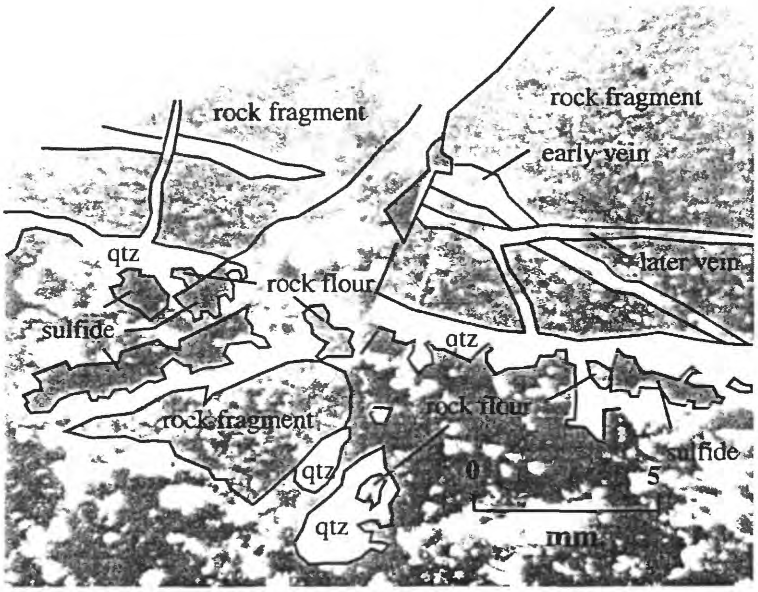

Figure 5. Photomicrograph of hydrothermal breccia (Ambon 4) in transmitted light.

Table 1. Chemical analyses of selected grab samples from the Hila prospect. Detection limits for selected elements are listed beneath the chemical symbol. The limits listed apply to samples Ambon 1, Ambon 2, and Ambon 3. Detection levels for sample Ambon 4 are 10 times the limits listed beneath the chemical symbols. All values are in ppm. N indicates the element was not detected at the level indicated.

Sample	Au (0.001)	Ag (0.07)	As (0.07)	Bi (0.07)	Cd (0.05)	Cu (0.05)	Mo (.09)	Pb (0.07)	Sb (0.07)	Zn (0.05)
Ambon 1	<0.002	N	5.43	N	2.94	26.4	0.917	4.08	N	530.
Ambon 2	<0.002	0.112	2.66	1.06	0.06	257.	0.256	2.26	N	300.
Ambon 3	0.010	0.136	8.49	2.36	1.30	290.	0.946	9.00	N	488.
Ambon 4	0.014	0.817	15.1	N	N	1550.	N	N	N	16.4

The geochemical analyses presented in table 1 are consistent with the petrography of the samples. Petrographically, Ambon 1 is the least mineralized and Ambon 4 is the most mineralized sample. Ambon 2 and 3 are intermediate between Ambon 1 and 4. Ambon 2, 3, and 4 show evidence of having been located near fractures that were conduits for hydrothermal fluids. These more intensely mineralized samples are characterized geochemically by the element suite Cu, Au, Ag. Traces of As and Bi also may be associated with the mineralization. Chalcopyrite was observed in trace amounts in Ambon 2 and 3, and was abundant in Ambon 4. It was not observed in Ambon 1. Although the number of samples from the Hila occurrence is few, the results appear to be consistent with those obtained from porphyry Cu-Au deposits such as Tanama and Helecho (Cox, 1985).

Interpretation

The mineralized veins and stockwork of the Hila prospect possibly represent the peripheral part (top or side) of a porphyry Cu-Au deposit (see figure 7 from Cox, 1986 and Cox and Singer, 1992). Geologic characteristics

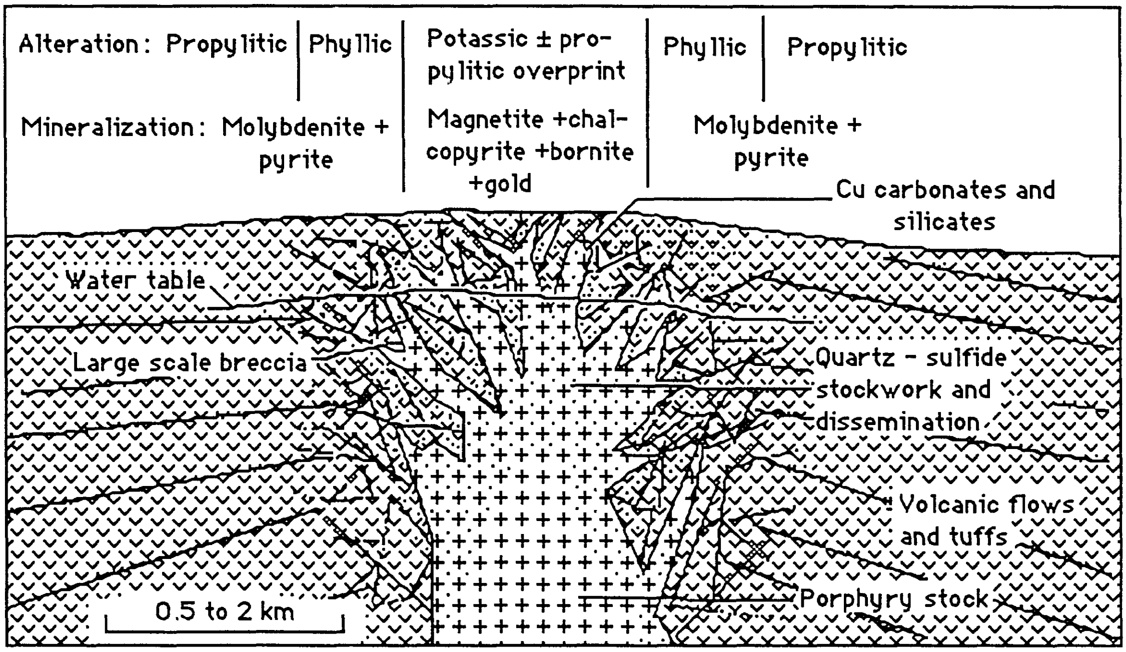

Figure 7. Diagramatic cross section of a porphyry Cu-Au deposit. From Cox (1986).

suggesting this deposit type include the tectonic setting of Ambon, the relatively shallow level of emplacement of the mineralization suggested by the young andesite host, the type of alteration, and the mineralogy of the occurrence. The main characteristic of the prospect that would be unusual in a porphyry Cu-Au deposit is the biotite cordierite granite intrusions associated with the Ambon volcanics. While a connection between the mineralization and these granites is not established, they occur in close proximity both temporally and spatially. Such a genetic relation would increase the likelihood that undiscovered deposits might be found in the southwestern part of Ambon Island where the granite crops out, and therefore this is an important relation to either establish or refute. The presence of biotite cordierite granite probably reflects the presence of continental crust beneath Ambon.

Porphyry Cu-Au deposits already known in Indonesia include Kaputusan, Sungai Mak, Cabang Kiri, Batu Hijau, and Grasberg-Ertsberg (Van Leeuwan, 1994). These deposits contain 0.2, 0.6, 0.6, 4.7, and 24 million tons of copper and 14.7, 32.8, 79, 390, and 2560 tons of gold respectively. Eighty percent of deposits of this type in the worldwide model (Singer and Cox, 1986) have sizes between 25 and 400 million tonnes (figure 7). Eighty percent have copper grades between 0.35 and 0.72 percent (figure 8), and eighty percent have gold grades between 0.2 and 0.72 ppm (figure 9).

The geologic setting and geochemical data for the Hila prospect are also consistent with several other mineral deposit types including: polymetallic veins and Sado type epithermal veins.

Suggestions for Prospecting

The possible presence of porphyry Cu-Au deposits on Ambon deserves further study. Initial studies should include a geochemical orientation study of sediments in the streams that drain the Hila prospect. If these studies indicate that stream sediment geochemistry is an effective mechanism for identifying drainages with mineral deposits, a survey of the island, or at least the western half of the main, northern part of the island, should be undertaken. Other investigations that should be undertaken include a remote sensing study of the vegetation and of linear and other structural features, and traverses across selected parts of the western half of the northern peninsula, and a magnetic survey. Results of these studies should be sufficient to determine if and where additional site specific studies should be undertaken.

Acknowledgements

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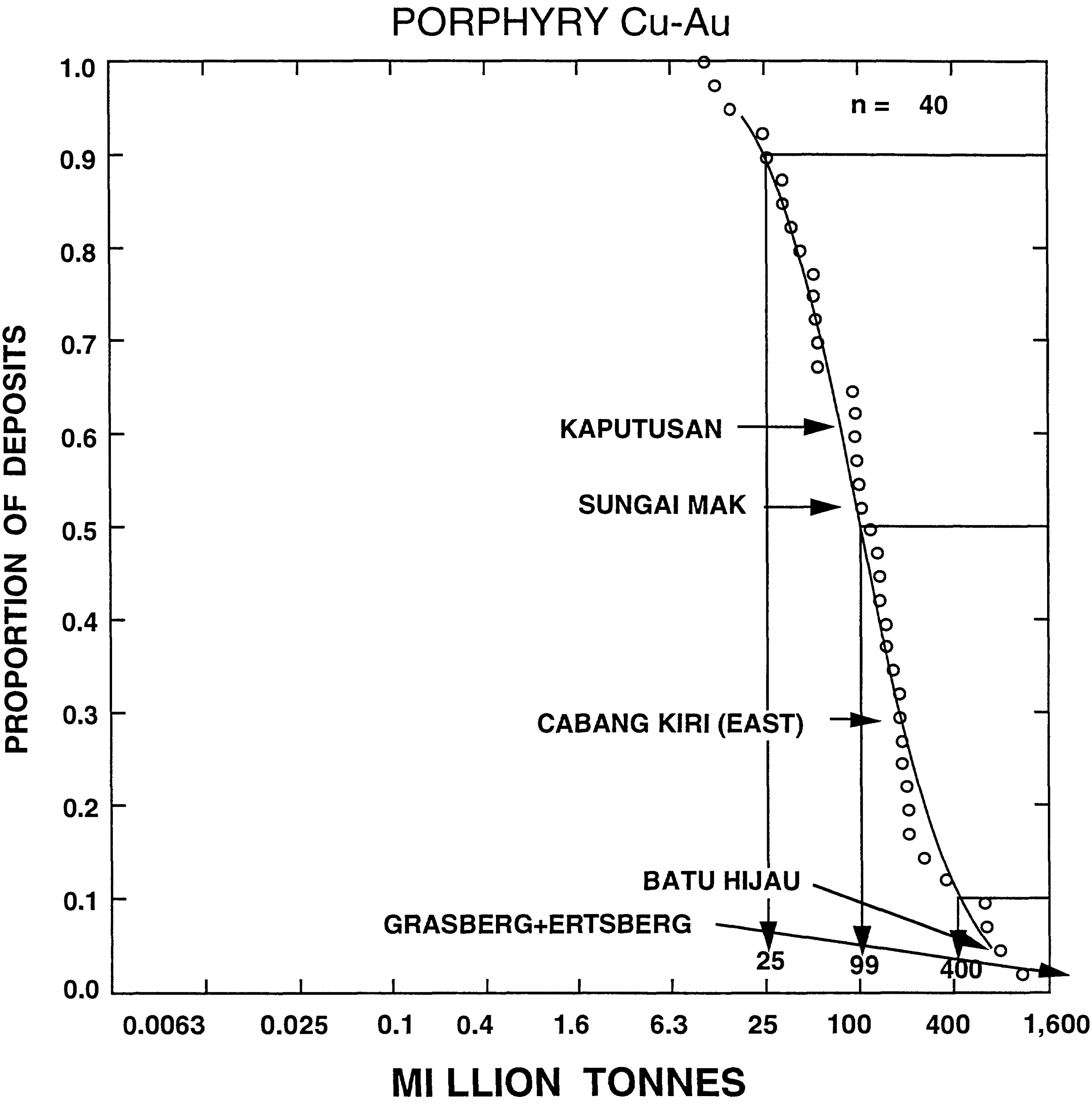

Figure 7. Tonnages of porphyry Cu-Au deposits (modified from Singer and Cox, 1986).

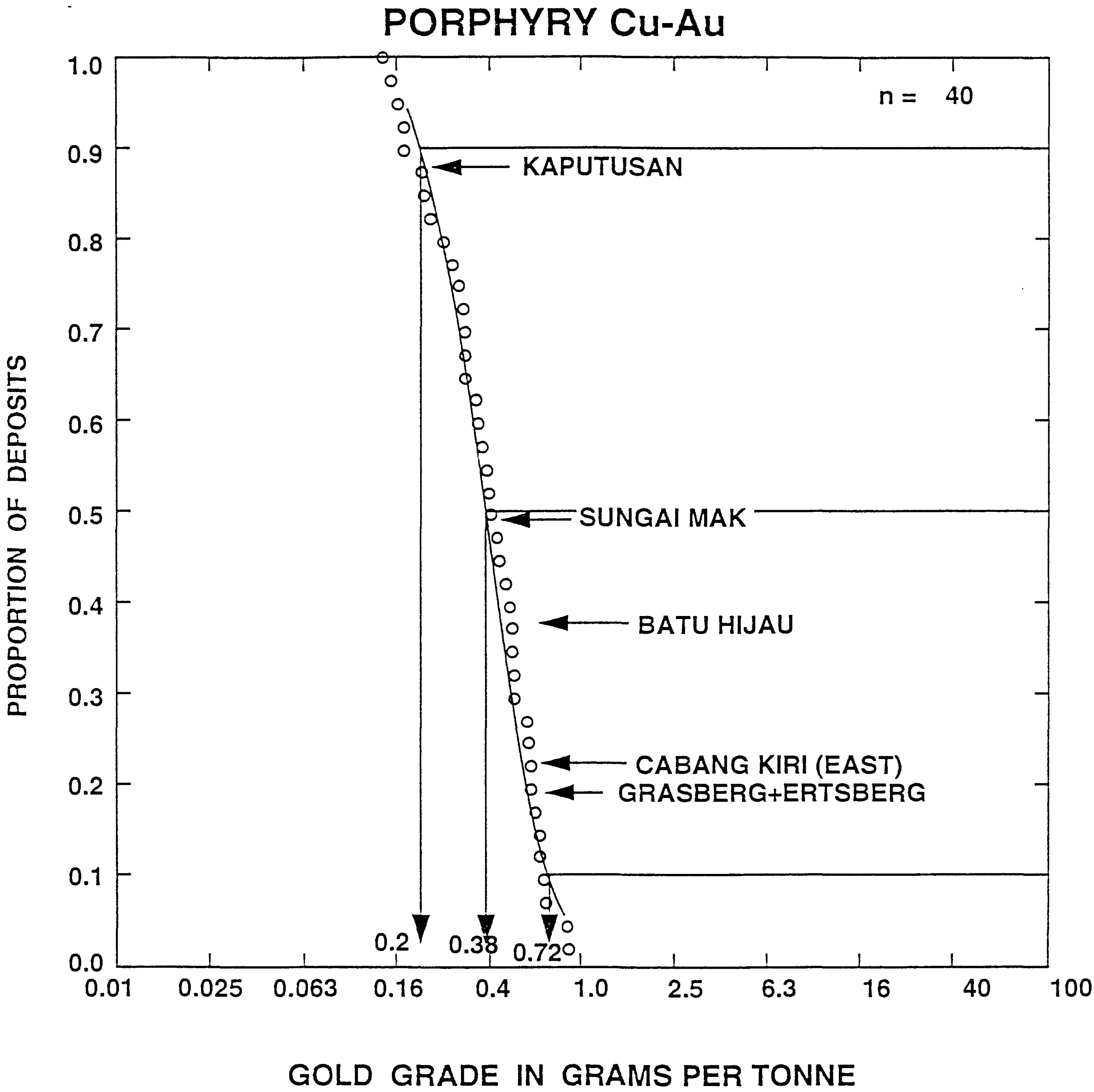

Figure 9. Gold grades of porphyry Cu-Au deposits (modified from Singer and Cox, 1986).

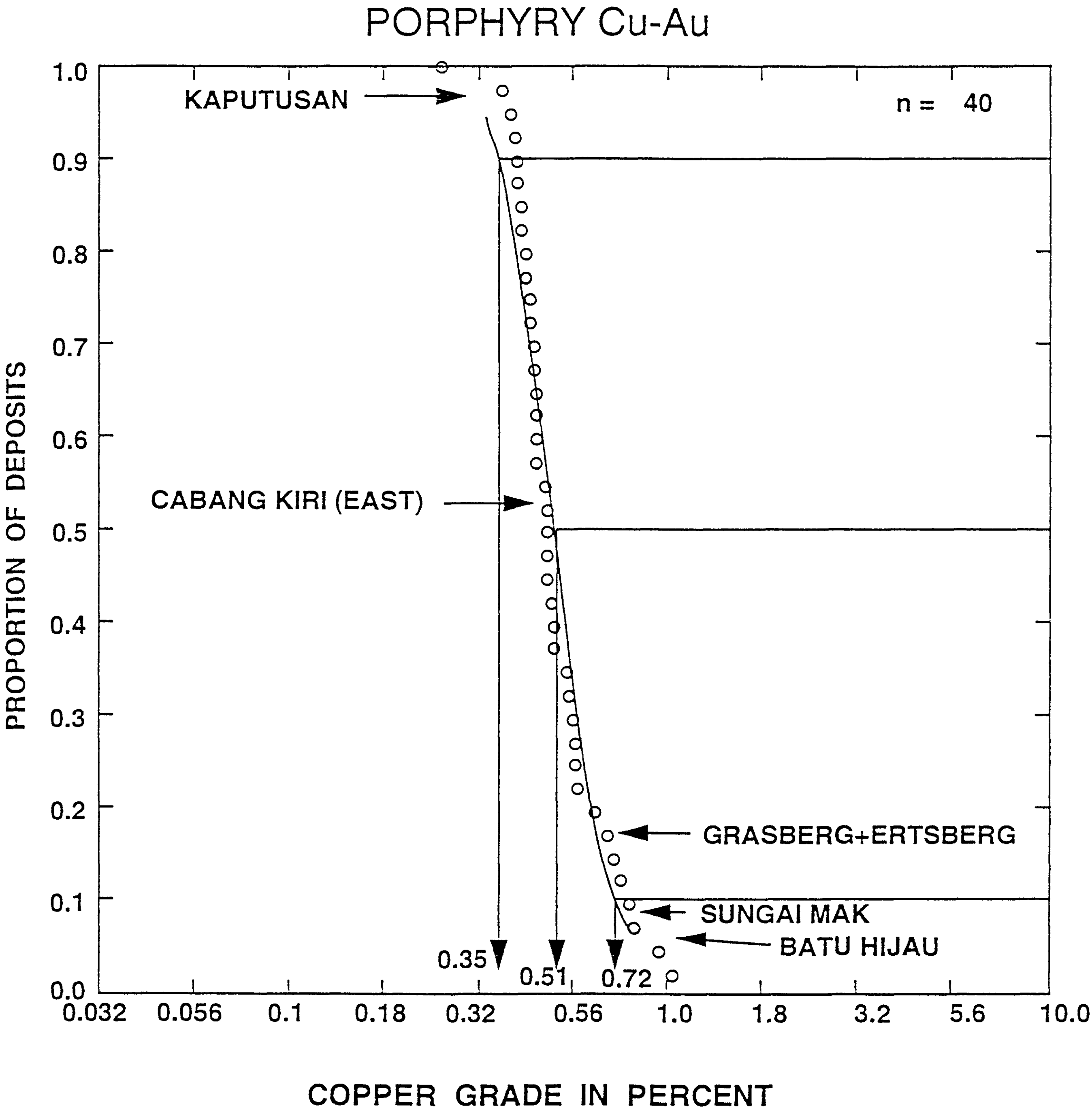

Figure 8. Copper grades of porphyry Cu-Au deposits (modified from Singer and Cox, 1986)

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