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DESCRIPTIVE AND GRADE-TONNAGE MODELS OF ARCHEAN LOW-SULFIDE Au-QUARTZ VEINS AND A REVISED GRADE-TONNAGE MODEL OF HOMESTAKE Au

by

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DESCRIPTIVE AND GRADE-TONNAGE MODELS OF ARCHEAN LOW-SULFIDE Au-QUARTZ VEINS AND A REVISED GRADE-TONNAGE MODEL OF HOMESTAKE Au (Model 36b.2)

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Descriptive model of Archean low-sulfide Au-quartz veins

INTRODUCTION

This model(36b.2) is for low-sulfide Au-Quartz vein deposits of Archean age and applies to 90 percent of the deposits formerly classified as Homestake deposits (model 36b) by Berger (1986a) and the grade and tonnage model by Mosier (1986). Their former classification as Homestake deposits required that the deposits be hosted principally by iron-formation or chemical sediments. However, most Archean gold deposits do not meet this requirement. The model presented here applies to most gold deposits in Archean terranes. Several studies in the Superior Province of Canada and Western Australia (see Colvine and others, 1988; Groves and others, 1989) have shown that these deposits occur in most of the rock types that make up Archean greenstone belts. The Archean deposits share most geologic characteristics with Proterozoic and Phanerozoic low-sulfide Au-quartz veins as described by Berger, 1986b (model 36a) (e.g. Juneau, Alaska; Carolin and Bralorne, B.C.; Motherlode and Grass Valley, California; Bendigo and Ballarat, Australia) but have grade and tonnage distinct from those of the low-sulfide Au-quartz veins presented by Bliss (1986). This descriptive model for Archean low-sulfide gold deposits does not require the presence of iron-rich chemical metasedimenary rocks as a diagnostic criteria in defining permissive tracts and it serves to emphasize the importance of structural control on the formation of these deposits.

BRIEF DESCRIPTION

Synonym: Shear-zone-hosted gold, Archean quartz-carbonate vein gold deposits, Archean lode gold, Archean mesothermal gold.

General references: Colvine and others (1988); Eckstrand, (1984); Groves and Foster (1991); Hodgson (1989); Roberts (1987); Hodgson and MacGeehan (1982)

Description: Quartz with or without carbonate (calcite, ankerite, or siderite) veins and more rarely stockworks and zones of silicic and(or) carbonate replacement containing native gold, auriferous pyrite or arsenopyrite, electrum, and more rarely gold in telluride minerals.

Typical deposits: Dome and Pamour mines at Timmins, Campbell mine at Red Lake, and Kerr Addison mine, Kirkland Lake camp, Ontario; Sigma mine, Quebec, Canada; Con and Giant Yellowknife mines, N.W.T.; Norseman, Kalgoorlie, Golden Mile, Australia; Ropes mine, Michigan, U.S.A. Porphyry-associated deposits at Camflo, Barnat, Hollinger, Lamaque, Perron, McIntyre, and Renabie, Canada.

Distinguishing features: Native gold is most commonly associated with small amounts of disseminated pyrite or pyrrhotite in well-developed quartz veins or stockworks with persistent sericite-carbonate alteration haloes in highly deformed, Archean host rocks that have been regionally metamorphosed to low- or medium-grades.

Relative importance: These deposits, with total worldwide production at least 9,900 m.t., account for the second largest amount of gold production of any major mineral deposit type after the Witwatersrand-type paleo-conglomerate-hosted deposits of South Africa (Groves and Foster, 1991). They are found in every major Archean craton.

Commodities: Au $^{+}$/- Ag

Other commodities: Cu $^{+}$/- Zn $^{+}$/- Pb $^{+}$/- W $^{+}$/- Mo

Associated deposits: Homestake Au (model 36b), alluvial or marine placers

Unrelated deposit types in the same geologic setting:
Volcanogenic massive sulfide and komatiitic nickel deposits and iron-formation.

REGIONAL GEOLOGIC ATTRIBUTES

Tectonic setting: Most are found in Archean greenstone belts or their associated intrusions along highly-deformed, steeply-dipping shear-zones. Most of the shear-zones form at major structural discontinuities near the contact between major sedimentary and volcanic rock sequences, are sub parallel to stratigraphy, continuous, or anastomosing over distances of greater than 30 km, and are as much as 2 km wide.

Age range: Archean. Usually younger (20-100 m.y.) than the last period of regional deformation and pluton emplacement (see, Hodgson and Hamilton, 1989; Hanes and others, 1992).

LOCAL GEOLOGIC ATTRIBUTES

Host Rocks: Metamorphosed, highly-altered, supracrustal rocks; e.g., most commonly in tholeiitic basalts, komatiites or their volcaniclastic or subvolcanic equivalents; less commonly in felsic volcanic rocks, graywacke and conglomerate, tonalite-granodiorite-quartz monzonite or syenitic stocks, plugs and dikes (including subvolcanic intrusions). Deposits that contain both disseminated and fracture-controlled mineralization constitute "porphyry gold" deposits (Franklin and Thorpe, 1982). Most deposits occur in greenschist-facies metamorphic terranes.

Associated rocks: alkaline intrusive rocks and lamprophyre dikes.

Structural setting: Discrete veins, as much as tens of meters wide, occur in deformation zones in greenschist metamorphic domains where brittle or brittle-ductile fracturing is dominant. However, disseminated mineralization in broad zones (up to hundreds of meters wide) is present in higher-grade metamorphic domains or in rocks which have a high phyllosilicate content where ductile deformation does not favor the propagation of brittle fractures. Deposits may be spatially associated with plutonic bodies because of their structural properties rather than having a direct genetic relationship related to magmatism, although in some there may be a genetic link, i.e. Hollinger-McIntyre, Ontario. Individual veins are generally less than 10 meters thick and have strike lengths of less than 100 meters. In some large districts (e.g. Kirkland Lake district, Ontario) strike length may be up to 5 km with a width of 500 m and vertical continuity of at least 2 km.

Structure: Veins emplaced in crosscutting or layer-parallel shear zones, extensional zones, breccias, and more rarely in saddle reefs. Controlling structures are generally subvertical to vertical and kinematic indicators may show strike- and oblique-slip and normal and reverse shear-zones although flat structures may locally control veins. A high degree of structural complexity is caused by local contrasts in structural properties of host rocks. The development of conjugate shears during continuing transpressive deformation produces variable and complex vein geometries.

Ore controls: Gold is associated with disseminated sulfide minerals. The gold-bearing sulfide minerals are controlled by minor fractures, and occur in small irregular patches in quartz, in the wall rock immediately adjacent to the vein, or as disseminations or replacements in zones of highly altered and deformed rocks.

Ore deposit geometry: Ore bodies may be tabular to rod-shaped bodies formed by persistent or discontinuous veins and irregular bodies of gold-bearing quartz or tabular replacement zones. Orientation of the ore bodies may be related to the intersections of structural elements or the intersection of favorable structures with chemically- or structurally-favorable host rocks.

Alteration: The addition of CO_2, K, S, and H_20 is characteristic of alteration in most Archean low-sulfide gold deposits. Silica, Fe, Mg, and Al may be depleted in the areas of highest fluid flow and the typically immobile elements (e.g. Nb, rare-earth elements, Sc, Ti, V, and Zr,) may show mobile behavior in some deposits (see Robert and Brown, 1986). Most of the alteration products form during hydrolysis and carbonatization reactions and the alteration mineralogy is strongly influenced by the composition of the host rocks. Quartz veins are surrounded by silicification and carbonate minerals (dolomite, ankerite, magnetite or calcite), sericite, and chlorite in mafic and ultramafic volcanic rocks, and albite alteration in host rocks of all compositions. In felsic igneous and clastic sedimentary host rocks, calcite is the dominant carbonate and sericite the most common phyllosilicate. Tourmaline may be present near the veins, especially in altered epizonal felsic intrusions. Talc, dolomite, chlorite, and fuchsite are typical of altered ultramafic host rocks. Broad zones of silicification, rather than discrete quartz veins, are typical of replacement-type deposits. In rare instances where hydrothermal conditions exceed greenschist-facies temperature and pressure conditions, amphibolite-facies indicator minerals such as chloritoid, biotite, anthophyllite, cordierite, garnet, andalusite, talc, and hornblende may be present with sericite and carbonate minerals depending on the composition of the host rocks.

Typical alteration dimensions: Carbonate minerals may form either a restricted alteration zone that ranges from a few meters to tens of meters away from small-scale, vein-controlling shear zones or may pervasively alter host rocks within regional shear zones that control gold deposition in zones that may range up to a kilometer or more in width. Visible bleaching caused by extensive silicification, sericitization, and albitization, may be developed on the scale of a few meters to tens of meters beyond individual veins. Subtle alteration, mainly characterized by sericite and carbonate minerals, may extend tens of meters outward from the bleached zone. A chlorite-carbonate mineral envelope may form outside the sericite-carbonate zone, in zones tens of meters wide.

Zoning: Hydrolysis and carbonatization of ferromagnesian minerals and iron oxides in mafic rocks often results in a distinctive, bleached inner zone containing the assemblage dolomite-sericite-quartz-pyrite (+/- biotite) and an outer zone containing chlorite-calcite (+/- albite). In ultramafic host rocks, the mineral assemblage quartz-fuchsite-dolomite-pyrite is surrounded by the assemblage talc-ferrodolomite-chlorite-pyrite. In mafic and ultramafic host rocks carbonate minerals are typically zoned from dolomite-ankerite near the vein to calcite at the periphery of alteration. Silica may be somewhat depleted in the outer alteration zones.

Effects of weathering: In areas of intense weathering in subtropical to tropical climates, production of saprolite results in leaching of the mobile alkali-elements Ca, Mg, Na, and K, as well as most metals originally present in sulfide minerals. Hypogene alteration minerals (carbonates, sericite, and chlorite) and sulfide minerals typically found in gold deposits, weather to form clay-rich saprolite and oxide and hydroxide minerals. The distance over which gold is chemically mobile during intense tropical weathering is limited, leading to the development of gold-rich saprolite usually directly overlying the hypogene source. Some coarsening of the particle size of gold may occur during chemical weathering and enrichment related to the mechanical accumulation during the slow erosion of saprolite (lag deposits)(Bowell and others, 1991; Lecomte and Colin, 1989; Michel, 1987; Mann, 1984). Mechanical weathering and erosion may provide a source of metal for alluvial and (or) marine placers.

Effects of metamorphism: Most deposits range from syn- to post-peak metamorphic in age and therefore the alteration mineralogy and structure of the deposits are not affected, in the absence of a superimposed metamorphic episode.

Ore mineralogy: Principal ore minerals are native gold, electrum, or gold in pyrite, pyrrhotite, arsenopyrite or minor amounts of Au-Ag telluride minerals. Galena, sphalerite, chalcopyrite, molybdenite, stibnite, and scheelite (common in deposits associated with quartz-phyric felsic rocks), magnetite, and hematite are common accessory minerals; deposits may rarely contain sulfarsenide or sulfosalt minerals.

Gangue minerals: Commonly quartz, calcite, ankerite, siderite; locally tourmaline content may be significant in wallrocks and in veins.

Isotopic signatures: Values of ^{18}O (SMOW) for gold-bearing quartz veins range from about 10-16 per mil (Colvine and others, 1988). Calculated ^{18}O for the hydrothermal fluid ranges from 2.5 to 10 per mil, a range consistent with magmatic, metamorphic, or meteoric fluid source. A small number of hydrogen isotope analyses of quartz and hydrothermal biotite and chlorite range from -50 to -87 per mil with D of water in equilibrium with these phases ranging from -30 to -80 per mil (Kerrich and Watson, 1984; Golding and Wilson, 1987). Water from fluid inclusions in quartz veins shows a wide range in D from +10 to -60 per mil (Fyon, 1986). Most ^{34}S (CDT) values of sulfide minerals are near 0 per mil, indicating that sulfur was derived directly from an igneous source or metamorphically from metaigneous rocks (Colvine and others, 1988). In a few districts, ^{34}S of sulfide minerals may range from -2 to -16 per mil consistent with sulfur transport in relatively oxidizing solutions derived by exsolution from a magmatic source (Cameron and Hattori, 1987) or oxidation of sulfur-bearing hydrothermal fluids during carbonate alteration of magnetite (Phillips and others, 1986). Values of ^{13}C (PDB) of carbonate minerals accompanying gold-bearing quartz veins ranges from 3 to -11 permil with most in the range of -2 to -8 per mil. Although a source for the CO_2 cannot be unambiguously determined, alternatives include CO_2 derived from a magmatic source or the result of metamorphic decarbonatization of mantle-derived carbonate in alteration zones along deep fracture systems (see Groves and Foster, 1991).

Estimates of the ^{87}Sr/^{86}Sr ratios of source rock reservoir for the hydrothermal fluids ranges from 0.7010 to 0.7023, implying that the fluid may have, at least partially, been derived at lower crustal levels (Kerrich, 1986; Kerrich and others, 1987). Lead isotope studies of galenas from gold deposits also indicate that the source of lead was commonly not the greenstone host rocks and probably was derived, at least in part, from an older sialic basement (Groves and Foster, 1991)

Fluid inclusions: Ore fluids generally have low salinity (<6 wt% NaCl equivalent, commonly <2wt%), near-neutral pH, and are reducing and have high CO_2 contents (10-25 mole%). Inferred temperatures at the time of gold deposition range from 200-400^{o}C (commonly 250-350^{o}C) and pressure ranges from 1-4.5 kb (commonly 1-3.0 kb) (see Colvine and others, 1988 and Groves and Foster, 1991). Methane is reported from deposits where fluids may have interacted with underlying carbonaceous rocks.

Geochemical signatures: Gold is accompanied by the enrichment of the trace elements Ag, As, Au, B, Ba, Cr, Li, Mo, Rb, Sb, and W; local, low-level enrichment of Cu, Pb, and Zn may occur in some deposits (see Colvine and others, 1988). Au/Ag ratio averages 10:1 in ore (Colvine, 1989). Large amounts of CO_2, K_2O, S, and H_2O and lesser amounts of Ba, Na_2O, Rb, and Li are typically introduced into the wallrock surrounding veins.

Geophysical signatures: Regional linear aeromagnetic and gravity anomalies may indicate first and second order shear zones. Ground magnetic surveys and VLF EM surveys may indicate magnetic lows and EM conductors associated with quartz veins. Weak conductors may be present over the mineralized structure and extend into the altered host rocks. Disseminated sulfide minerals associated with gold may cause an IP anomaly. Silicification that commonly accompanies gold deposits may produce local resistivity highs near deposits. Potassium anomalies related to sericitic alteration may be detected by -ray spectrometry.

Other exploration guides:
1) Archean age.
2) major shear zones generally within 5 km of the deposits
3) greenschist or, less commonly, amphibolite regional metamorphic grade.
4) host rocks with high Fe^{2+}/Fe^{3+}.
5) presence of thin komatiitic or high-Mg basalt units.
6) molasse-type sediments indicating fault-related basin formed during shear-zone deformation.
7) presence of silicified, carbonatized, K-enriched, pyritized zones; fuchsite may be a guide in ultramafic rocks.

GRADE AND TONNAGE MODEL OF ARCHEAN LOW-SULFIDE Au-QUARTZ VEINS

Deposit data originally contained in the Homestake Au grade and tonnage model (model 36b by Mosier, 1986) that were not from chemical sediment-hosted deposits were used to construct the grade and tonnage model for the Archean low-sulfide Au-Quartz vein deposits. Data were revised with recent information, generally reflecting increases in reserves since the publication of the original data set in Cox and Singer (1986). Data for twenty-three of the original deposits were updated. Three deposits, included in the original data, were removed because they were Proterozoic in age. A total of eleven iron-formation-hosted deposits were removed and used in a revised Homestake Au grade and tonnage curves (see below). The entry for the Barberton area, South Africa, was replaced by data from twelve individual deposits, meeting the deposit criteria of Mosier (1986), i.e., that they be clearly separate deposits or that they are more than 1.6 km apart. Data from a total of forty-nine additional Archean deposits (including the twelve from the Barberton area) were added to the database to increase the geographic diversity of the model.

Statistics for the revised data are in table 1. The revisions and additions to the data set resulted in an increase in the median size (1.0 vs. 0.94 million metric tons), decreases in the median gold grade (8.8 vs. 9.2 g/t) and increase in the mean silver grade (4.5 vs. 1.6 g/t) when compared to the original Homestake model (36b) of Mosier (1986)). However, the two models are not statistically different (J.D., Bliss, written communication, 1994), because 80 percent of the deposit grades and tonnages of Mosier (1986) are unchanged and are included in this model. Comparison of the Archean low-sulfide Au-quartz vein model with the revised Homestake model (see below) shows a lower median size (1.0 vs. 3.4 million metric tons), higher median gold grade (8.8 vs. 8.0 g/t), and a higher mean silver grade (4.5 vs. 1.0 g/t). While these differences are noted, the two models are not statistically different in terms of gold or silver grades. However, the hypothesis that the revised Homestake model mean tonnage is equal to that for Archean low-sulfide Au-quartz veins was rejected (t-test) at the 1% confidence level. The revised Homestake deposits have a mean size that is statistically larger (J.D., Bliss written communication, 1994). Sizes and gold grades have a log normal distributions whereas the silver grade has a truncated distribution due to missing values. Gold grade does not correlate with silver grade (r=0.203, n=53) or with tonnage (r=-0.023, n=148).

Grade and tonnage curves for Archean low-sulfide Au-quartz vein deposits are shown in figures 1-3. The grade and tonnage data are in table 2.

Table 1. Summary statistics for grade and tonnage model of Archean low-sulfide Au-Quartz veins. Statistics for silver were calculated only from those deposits that reported silver. (J.D. Bliss, written communication, 1994).

variable	Mean	Std. Deviation	Std. Error	Variance	n	minimum	maximum	kurtosis	skewness
t	6.033	0.846	0.069	0.716	148	3.622	8.077	0.208	-0.030
Au (g/t)	0.936	0.229	0.019	0.052	148	0.462	1.462	-0.596	0.213
Ag (g/t)	0.217	0.565	0.077	0.319	53	-0.745	1.668	0.368	0.672

Logarithm (base 10) for tonnage, Au and Ag; Statistics generated using Abacus Concepts, StatView II and SPSS, Inc., SPSS for Windows[1]; t, metric ton; g/t, grams per metric ton; n, number of deposits.

[1] Any use of trade, product, or firm names in this report is for descriptive purposes only and does not imply endorsement by the U.S. government.

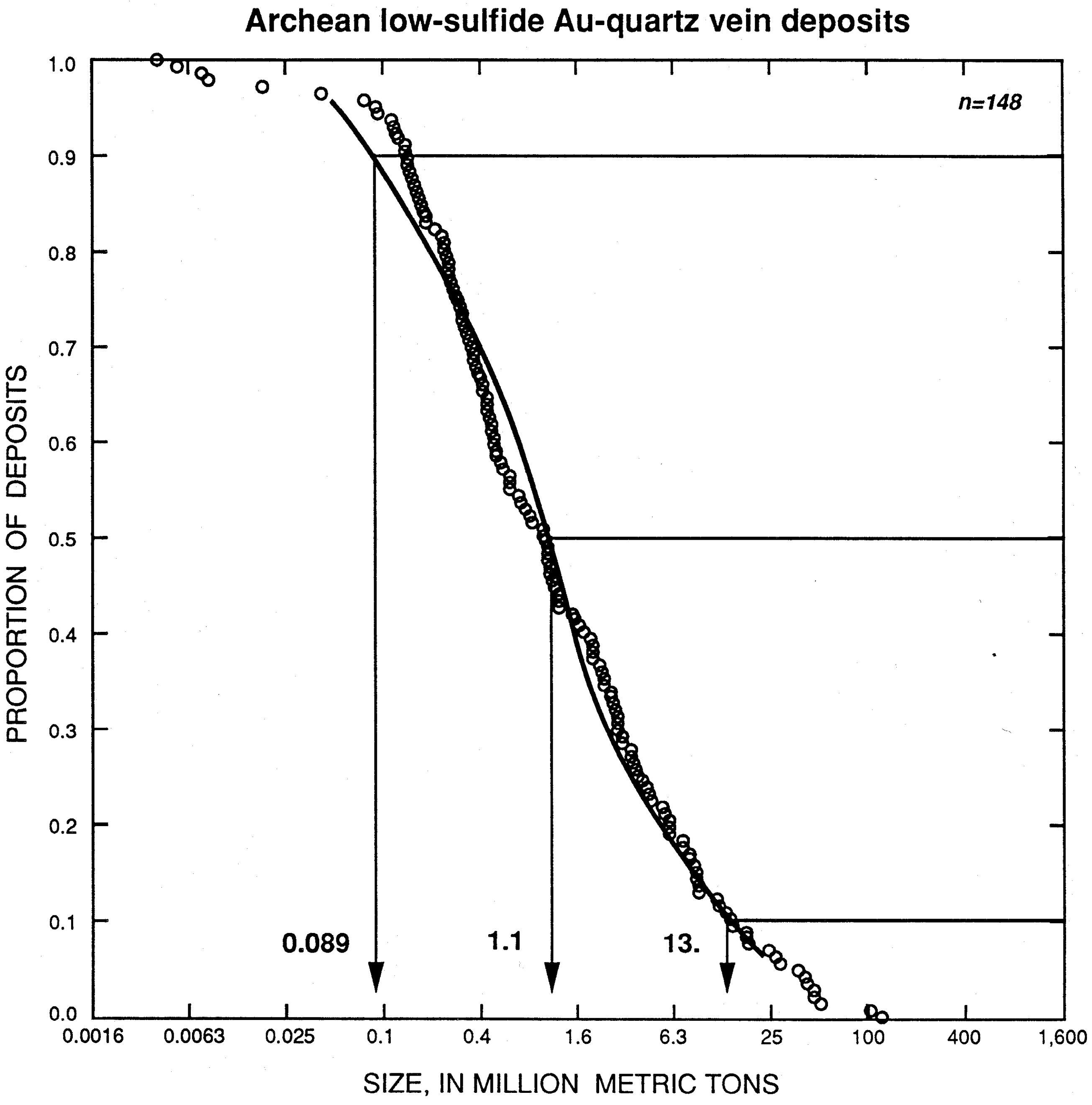

Figure 1. Tonnages (metric tons) of Archean low-sulfide Au-quartz vein deposits showing the tenth, fiftieth, and ninetieth percentile values

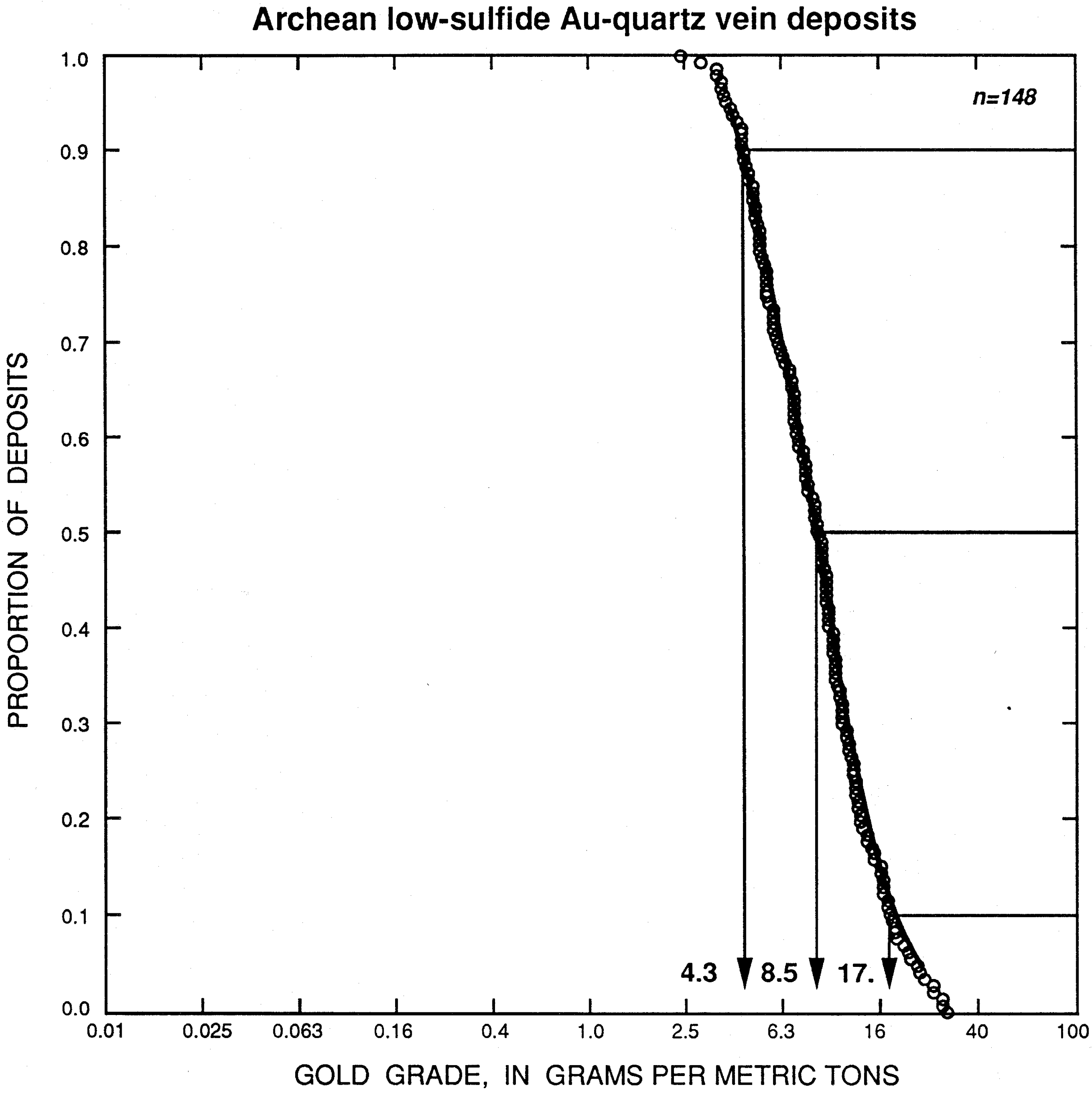

Figure 2. Gold grades (g/metric ton) of Archean low-sulfide Au-quartz vein deposits showing the tenth, fiftieth, and ninetieth percentile values.

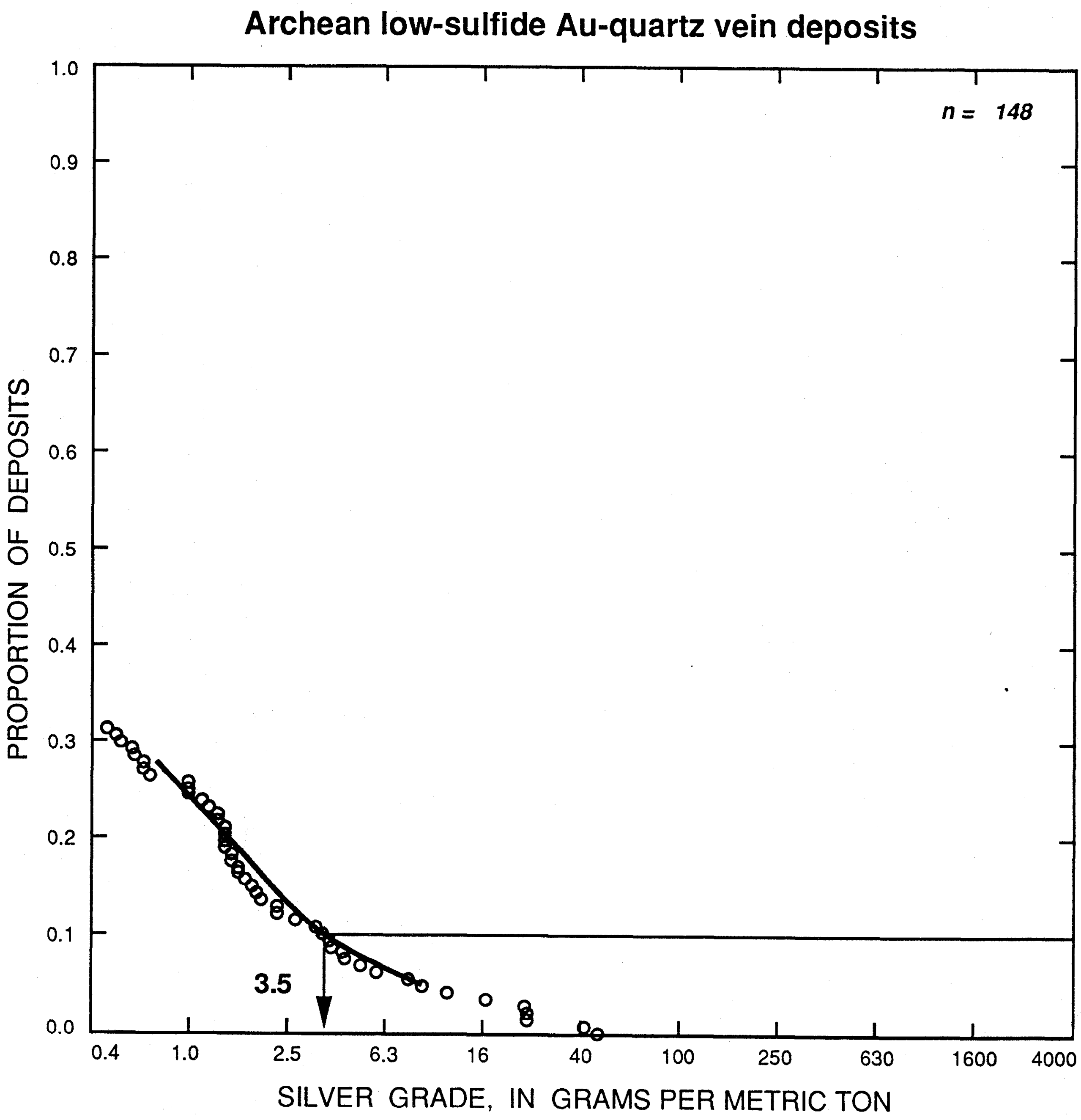

Figure 3. Silver grades (g/metric ton) of Archean low-sulfide Au-quartz vein deposits showing the tenth percentile value.

Table 2. Grades and tonnages of Archean low-sulfide Au-quartz vein deposits. Tonnages in million metric tons; Gold and silver grades in grams/metric ton. The locality abbreviations are those of Cox and Singer (1986) and Bliss, (1992). Data in bold italics are updated or changed from model 36b of Mosier (1986); deposits in lower case were not included in model 36b. Deposit with asterisk was excluded from grade and tonnage curves and descriptive statistics because it is an outlier in Au grade vs. tonnage plot.

deposits	country	Tons	Au grade	Ag grade	comment
Abercorn	ZIMB	126,420	17.6	0	production to 1977, Foster and others (1986)
ABINO	CNON	367,554	7	0	
AGASSIZ	CNON	2,720,000	4.45	40.8	
Agnes-Pioneer-Ivey-Woodbine	SAFR	3,603,521	7.1	0.35	production to 1983, Annhaesser (1986)
ANKERITE-AUNOR-DELNITE	CNON	14,499,448	9	0.65	
Anzac-JoJo	ZIMB	398,667	6	0	production to 1977, Foster and others (1986)
Arcturus	ZIMB	2,338,627	10.2	0	production to 1977, Foster and others (1986)
ARROWHEAD	CNQU	5,443	19.5	0	
ASHLEY	CNON	143,004	11	1.7	
Aurilandia	BRZL	500,000	5.4	0	reserves, Ladcerda (1991)
Aurumina	BRZL	184,000	7	0	weighted average grade, resources, Lacerda (1991)
B&S (Motopa)	ZIMB	2,194,186	4.3	0	production to 1977, Foster and others (1986)
BANKFIELD-TOMBILL	CNON	382,500	11	1.3	
BARBARA-SURPRISE	AUWA	***419,640***	***12.3***	0	Woodall (1990)
BARBER-LARDER	CNON	95,300	3.6	0	
Barbrook	SAFR	467,714	3.5	0	production to 1983, Annhaesser (1986)
BARRY HOLLINGER	CNON	242,889	8.9	8.9	
Beatrice	ZIMB	142,913	20.6	0	production to 1977, Foster and others (1986)
BELLEVUE	AUWA	***3,445,376***	***7.1***	0	Woodall (1990)
Bernheim Group	ZIMB	317,273	11	0	production to 1977, Foster and others (1986)
BIDGOOD-MOFFATT-HALL	CNON	547,000	9.3	4.2	
BIG BELL	AUWA	***24,194,357***	***3.5***	0	Woodall (1990)
BLACK RANGE-OROYA	AUWA	1,018,842	18.2	0	
Bonanza	SAFR	141,026	7.8	0	production to 1983, Annhaesser (1986)
BONNIEVALE	AUWA	343,098	16	0	
Bonsor-Yankee Doodle-Knights	ZIMB	798,300	10	0	production to 1977, Foster and others (1986)
BOUSCADILLAC-O'BRIEN-KEWAGAMA	CNQU	3,362,570	9.6	0	
BROULAN-HALLNOR-PAMOUR	CNON	28,267,690	5.4	0.46	spelling of Pamour
BUFFALO RED LAKE	CNON	121,562	7.5	0	
BURBANKS	AUWA	***445,103***	22.1	0	Woodall (1990)
Bushtick	ZIMB	2,785,926	5.4	0	production to 1977, Foster and others (1986)
CALDER-BOUSQUET	CNQU	156,000	5.8	0	
Cam and Motor	ZIMB	11,757,581	12.4	0	production to 1977, Foster and others (1986)
Camflo	CNQU	9,034,000	6.4	0	Sauve and Makila (1990)
CAMPBELL RED LAKE-DICKENSON	CNON	***26,244,061***	***16.7***	1.4	weighted average for grade, Fyon and others (1992)
Casa-Berardi	CNQU	11,400,000	7.91	0	pre-mining reserves in 1988, Pilote and others (1990)
CATHROY-LARDER	CNON	609,850	6.9	1.5	
CENTRAL MANITOBA	CNMN	413,719	12	1.96	
CHEMINIS-FERNLAND-OMEGA	CNON	1,961,070	4.5	0.6	

CHESTERVILLE	CNON	2,957,805	3.8	0.2	
Clutha-New Clewer	SAFR	313,571	7	0	production to 1983, Annhaesser (1986)
COOLGARDIE	AUWA	1,055,610	11.9	0	
COSMOPOLITAN	AUWA	***750,053***	***16.3***	0	Woodall (1990)
CULLATON LAKE	CNNT	286,000	25.4	0	
Dalny	ZIMB	5,489,359	7.8	0	production to 1977, Foster and others (1986)
DAVIDSON	CNON	8,501	8.9	0.5	
DAY DAWN-MAIN LINE	AUWA	***3,563,738***	***13***	0	Woodall (1990)
Daylight	SAFR	166,974	7.6	0	production to 1983, Annhaesser (1986)
DESANTIS	CNON	300,840	16	0.36	
DOME-PAYMASTER-PRESTON	CNON	40,648,260	9.5	1.6	
Dunraven	ZIMB	237,500	8.8	0	production to 1977, Foster and others (1986)
EDNA MAY	AUWA	***3,773,171***	***5.17***	0	Woodall (1990)
Eiffel Blue-Glencairn-Glenmore	ZIMB	599,682	15.7	0	production to 1977, Foster and others (1986)
EMU-GREAT EASTERN	AUWA	***7,720,583***	***4.3***	0	weighted average for grade, Woodall (1990)
Fortuna	SAFR	1,059,200	5	0.2	production to 1983, Annhaesser (1986)
FRASER'S	AUWA	***2,851,631***	***8.5***	0	Woodall (1990)
FULLER-TISDALE	CNON	1,984,283	5.1	0	
Gaika	ZIMB	2,545,000	8.6	0	production to 1977, Foster and others (1986)
GLADSTONE-SAND QUEEN	AUWA	***447,017***	***13.1***	0	Woodall (1990)
Globe-Phoenix	ZIMB	4,363,478	27.6	0	production to 1977, Foster and others (1986)
GOD'S LAKE	CNMN	490,914	10.7	1.8	
GOLD HAWK	CNON	499,000	9.3	0	
GOLD HILL	CNON	4,190	4.8	0	
GOLDEN EAGLE-MACKENZIE	CNON	2,298,730	9.3	2.7	
GOLDEN RIDGE	AUWA	254,847	17.1	0	
Golden Valley	ZIMB	1,228,565	22.3	0	production to 1977, Foster and others (1986)
GURNEY	CNMN	91,902	8.5	24	
HASAGA-HOWERY	CNON	5,802,410	3.7	1.3	
HOLLINGER-MCINTYRE	CNON	***100,900,000***	***9.9***	2.3	Wood and others (1986) without Moneta
HUTTI	INDA	1,083,300	12	0	
IDA H.	AUWA	***292,580***	***23.6***	0	Woodall (1990)
ISLAND LAKE	CNMN	7,819	25.4	0	
JASON	CNON	251,000	12.7	1.2	
JEROME	CNON	616,000	5.8	1.5	
Jessie	ZIMB	1,099,429	10.5	0	production to 1977, Foster and others (1986)
KALGOORLIE(GOLDEN MILE ETC)	AUWA	***119,445,121***	***10.7***	0	Woodall (1990)
KERR ADDISON	CNON	***36,021,000***	9.3	0.52	Fyon and others (1992)
KIABAKARI	TNZN	1,041,700	9.6	1.4	
Kiena	CNQU	7,100,000	5.4	0	production and reserves (12-31-85), Cormier (1986)
KILO-MOTO	CNGO	13,235,300	20.4	5	
KIRKLAND LAKE	CNON	49,336,090	14.7	5.8	
KOLAR	INDA	45,400,000	17.8	0	
LAGUERRE*	CNON	9,978,990	1.7	1.2	
LAPA CADILLAC	CNQU	373,000	4.4	0	
Legion-Pickwick	ZIMB	211,111	9	0	production to 1977, Foster and others (1986)
LEITCH-SAND RIVR	CNON	994,000	28	1.14	
LINGMAN	CNON	1,074,000	10	0	
LITTLE LONG LAC	CNON	1,615,250	11.7	1	
Lonely	ZIMB	1,986,914	17.5	0	production to 1977, Foster and others (1986)

MADSEN	CNON	***8,246,758***	***9.1***	1.9	Fyon and others (1992)
MAGNET CONSOLIDATED	CNON	327,000	14.4	1.6	
Malartic-East Malartic-Canadian Malartic-Barnat-Sladen	CNQU	45,291,554	4.7	0	Sansfacon and Hubert (1990)
Mara Rosa	BRZL	1,479,950	4.7	0	reserves proven and indicated, Lacerda (1991)
MARBLE BAR (COMET)	AUWA	253,103	29	0	
MARTIN-BIRD	CNON	164,300	5.1	0	
MATACHEWAN CONSOLIDATED-YOUNG DAVIDSON	CNON	8,757,437	3.4	1	
MATONA-STAIRS	CNON	172,124	13.7	3.8	
Mazoe Group	ZIMB	1,238,017	11.6	0	production to 1977, Foster and others (1986)
MCFINLEY	CNON	152,000	6.1	46.6	
MCMARMAC	CNON	138,800	10.97	0.34	
MCWATTERS	CNQU	707,600	9.5	0	
Meia Pataca	BRZL	187,022	2.9	0	reserves, proven and indicated, Ladcerda (1991)
MENZIES	AUWA	966,840	23.6	0	
Mina III	BRZL	5,288,268	12.72	0	proven reserves, Lacerda (1991)
MINTO-TYRANITE	CNON	266,540	5.3	0.7	
MORRIS KIRKLAND	CNON	115,441	4.5	7.9	
Muriel	ZIMB	1,539,496	13.9	0	production to 1977, Foster and others (1986)
NAYBOB	CNON	1,208,214	4.8	0.59	
New Consort	SAFR	7,053,462	7.8	0.4	production to 1983, Annhaesser (1986)
NORSEMAN-DUNDAS	AUWA	7,743,320	13	0	
ORPIT	CNON	272,000	5.5	0	
Owl Creek	CNON	1,748,072	4.7	0	Coad and others (1986)
PADDY'S FLAT (MEEKATHARRA)	AUWA	***14,107,464***	***4.25***	0	Woodall (1990)
PALMER'S FIND	AUWA	310,728	15.9	0	
Patchway	ZIMB	1,165,310	11.3	0	production to 1977, Foster and others (1986)
Pigg's Peak	SWAZ	363,627	10.2	0	production to 1983, Annhaesser (1986)
Prestea	GHNA	18,058,000	10.3	0	production to 1988, Appiah and others (1991)
QUEENSTON	CNON	454,000	4.8	0	
R.O. Extension-Primrose-Skeleton	ZIMB	258,862	12.3	0	production to 1977, Foster and others (1986)
RED CREST	CNON	43,040	9.3	3.7	
RED LAKE GOLDEN SHORE	CNON	78,320	8.5	1.4	
Red Rose	ZIMB	120,272	14.7	0	production to 1977, Foster and others (1986)
Ropes, Michigan	USMI	4,589,800	3.4	24	Skillings (1983); Sims and Day (1992); Broderick (1945)
Rosetta	SAFR	233,030	9.9	1.4	production to 1983, Annhaesser (1986)
ROSS	CNON	3,998,000	5.8	11.3	
ROUYN MERGER	CNQU	149,000	5.8	0	
SANSHAW	CNQU	181,000	6.9	0	
SHAMVA-CYMRIC	ZIMB	9,000,000	5.1	0	
Sheba-Fairview-Golden Quarry	SAFR	8,744,000	12	0.35	production to 1983, Annhaesser (1986)
Sigma-Lamaque	CNQU	41,044,776	6.7	0	Robert (1986)
SLIPPERY GIMLET	AUWA	***2,243,099***	***4.4***	0	Woodall (1990)
SON OF GWALIA	AUWA	***17,636,504***	***5.9***	0	Woodall (1990)
STADACONA	CNQU	2,982,000	5.4	0	
STARRATT-OLSEN	CNON	840,100	6.3	1	
Sunbeam-Piper Moss	ZIMB	444,051	7.9	0	production to 1977, Foster and others (1986)
Surprise Group	ZIMB	468,070	11.4	0	production to 1977, Foster and others (1986)

TALMORA LONGLAC	CNON	18,634	7.2	0.18	
Three Sisters	SAFR	351,912	6.8	2.3	production to 1983, Annhaesser (1986)
TIMONI	AUWA	477,933	15.7	0	
TRITON (REEDY'S, KURARA)	AUWA	***5,948,949***	***3.9***	0	Woodall (1990)
UCHI	CNON	686,740	5.1	0.65	
Umtali District	ZIMB	2,588,358	6.7	0	production to 1977, Foster and others (1986)
UPPER BEAVER	CNON	527,700	8.2	3.5	
UPPER CANADA	CNON	4,295,150	10.3	4.3	
WASA LAKE	CNQU	1,896,000	4.3	0	
WHITE FEATHER	AUWA	***2,617,417***	***7.28***	0	Woodall (1990)
WILMAR-ANNCO-COCHENOUR-WILLA	CNON	5,832,750	8.6	3.3	
WILUNA-MOONLIGHT	AUWA	***17,515,924***	***4.1***	0	Woodall (1990)
YOUANMI	AUWA	***2,810,330***	***6.8***	0	Woodall (1990)

REVISED GRADE AND TONNAGE MODEL OF HOMESTAKE AU DEPOSITS

This grade and tonnage model is a revision of model 36b by Mosier, 1986). Data for eleven chemical sediment-hosted deposits that were included in the original Homestake Au database were used or were updated with more recent information. Information from twenty additional deposits was added. This restructuring was made necessary by the reclassification of 90 percent of the original Homestake Au deposits as Archean low-sulfide Au-quartz vein deposits (model 36c; Klein, 1994). One deposits, the Bob, was rejected because it was not similar to the other deposits in grade and(or) tonnage. The new curves show an increase in the median size and a decrease in median Au grade from the original Homestake Au curves (n=30).

The distribution statistics for the revised data are in table 3. The revisions and additions to the data set resulted in an increase in the median size (3.4 vs. 0.94 million metric tons), decreases in the median gold grade (8.0 vs. 9.2 g/t) and a decrease in mean silver grades (1.0 vs. 1.6 g\t) when compared to the original Homestake model (36b) of Mosier (1986). While these differences are present, the two models are not statistically different in terms of gold or silver grades. However, The hypothesis that the revised Homestake deposit median tonnage is equal to that of the Homestake Au deposits by Mosier (1986) was rejected (t-test) at the 1-percent confidence level (written communication, J.D., Bliss, 1994). The revised Homestake Au deposits have a mean size that is statistically larger. The tonnage and gold grade have a log normal distribution whereas the silver grade has a truncated distribution due to missing values. Gold grade does not correlate with silver grade (r=-0.324, n=7) or with tonnage (r=-0.023, n=30). Grade and tonnage curves for the revised Homestake Au model are shown in figures 4-6. The grade and tonnage data are given in table 4.

Table 3. Summary statistics of grade-tonnage model of revised Homestake Au. Statistics for silver were calculated only from those deposits that reported silver. (written communication, J.D. Bliss, 1994).

variable	Mean	Std. Deviation	Std. Error	Variance	n	minimum	maximum	kurtosis	skewness
t	6.496	0.692	0.129	0.479	31	5.104	8.169	0.639	-0.311
Au (g/t)	0.855	0.211	0.04	0.044	31	0.279	1.23	0.785	-0.502
Ag (g/t)	0.0019	0.384	0.14	0.147	7	-0.569	0.314	-1.016	-1.038

Logarithm (base 10) for tonnage, Au and Ag; Statistics generated using Abacus Concepts, StatView II and SPSS, Inc., SPSS for Windows[1]; t, metric ton; g/t, grams per metric ton; n, number of deposits.

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[1] Any use of trade, product, or firm names in this report is for descriptive purposes only and does not imply endorsement by the U.S. government.

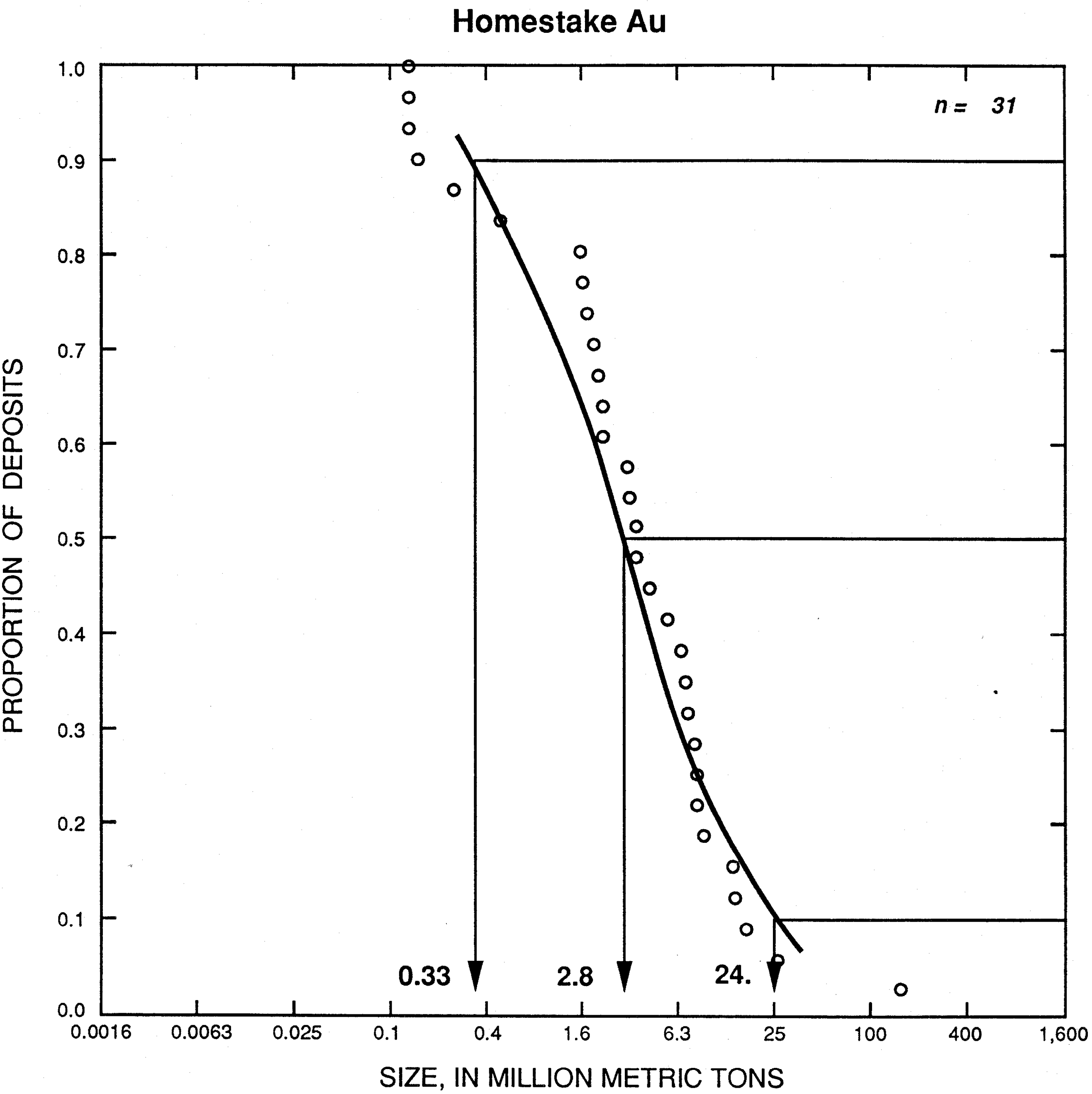

Figure 4. Revised tonnages (metric tons) for the Homestake Au model showing the tenth, fiftieth, and ninetieth percentile values.

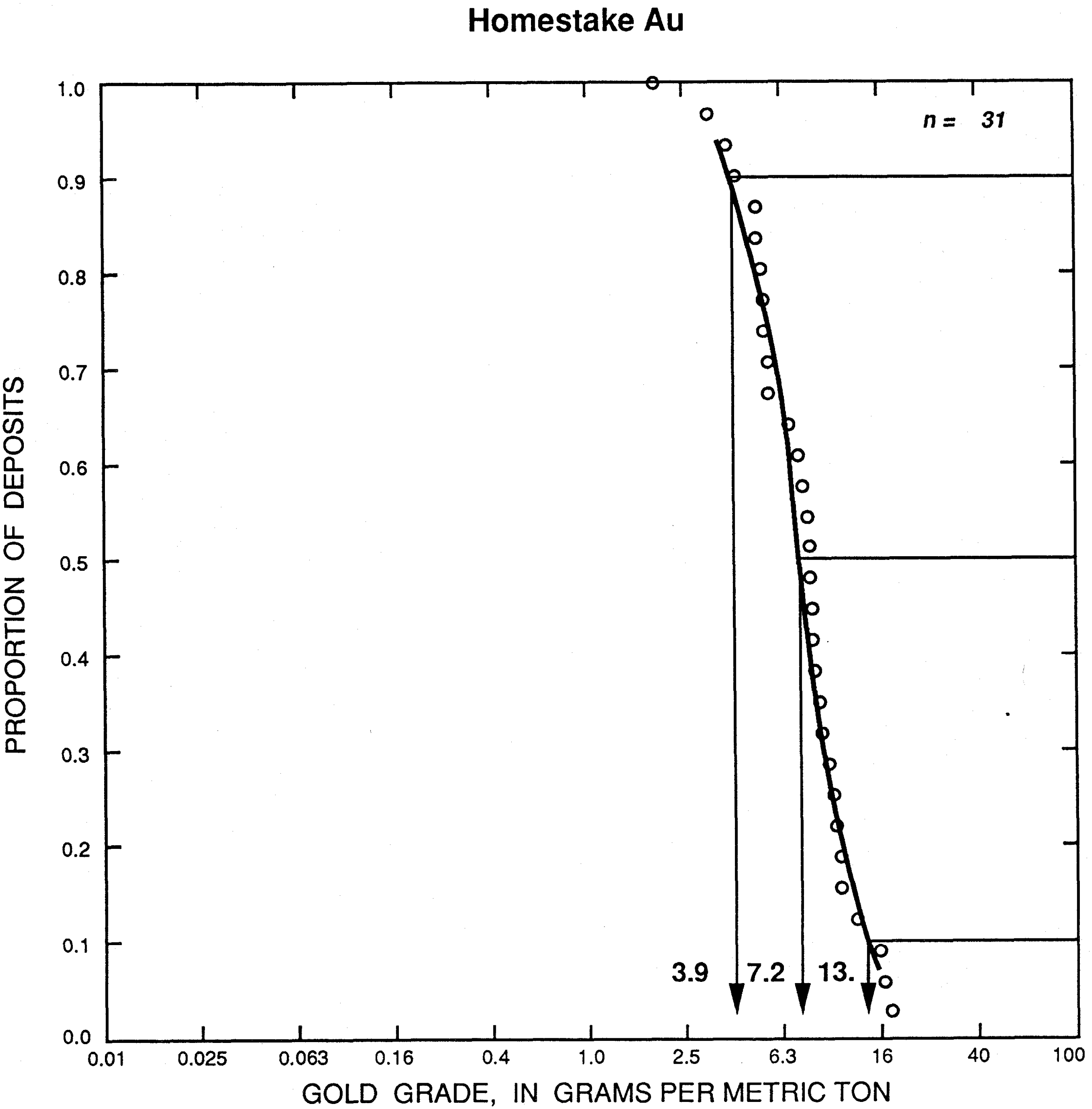

Figure 5. Revised gold grades (g/metric ton) for the Homestake Au model showing the tenth, fiftieth, and ninetieth percentile values.

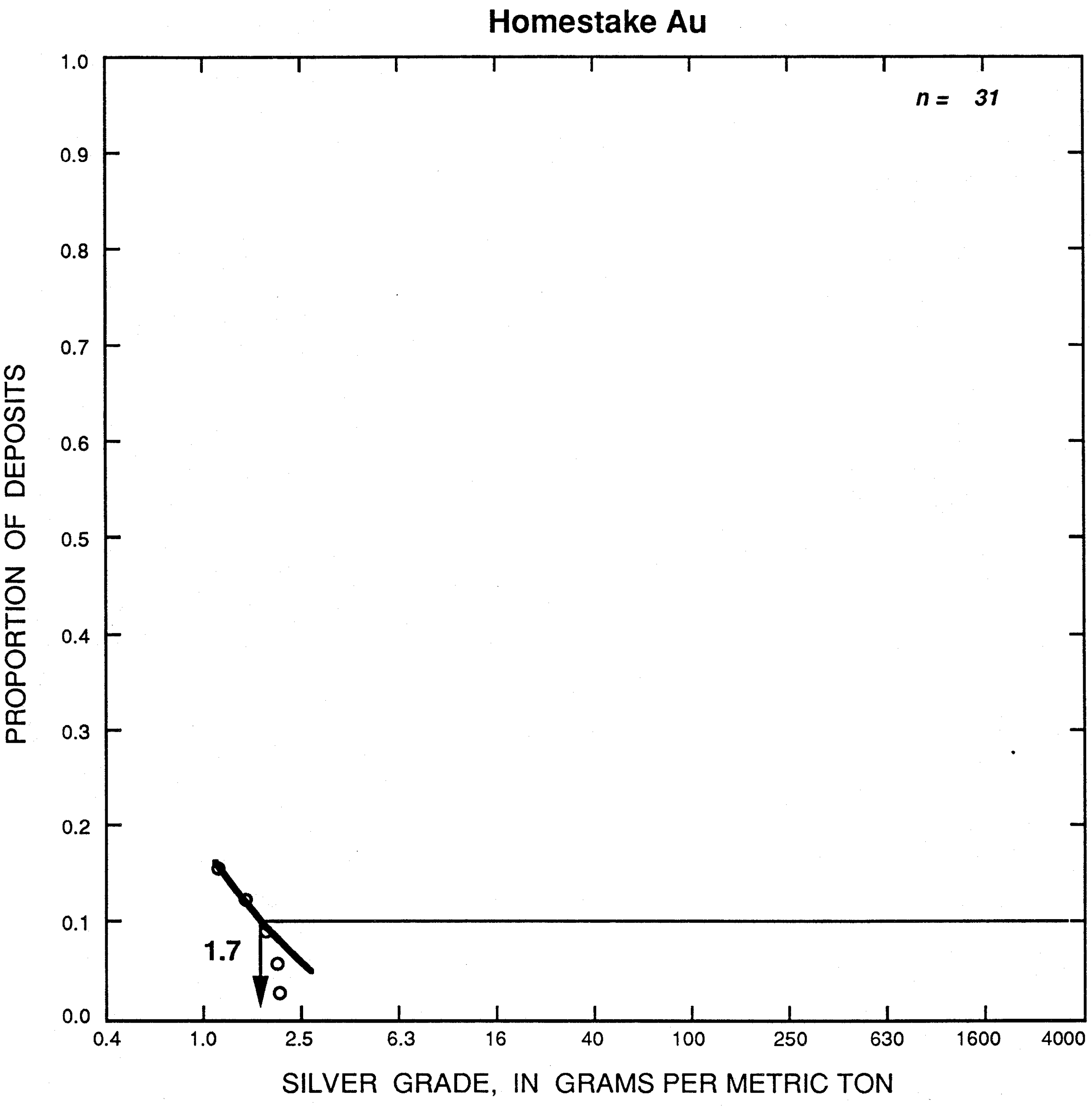

Figure 6. Revised silver grades (g/metric ton) for the Homestake Au model showing the tenth percentile value.

Table 4. Revised grades and tonnages of Homestake Au deposits. Tonnages in million metric tons; Gold and silver grades in grams/metric ton. The locality abbreviations are those of Cox and Singer (1986) and Bliss (1992). Deposits in capital letters from model 36b of Mosier (1986); data in bold italics updated or changed. Deposits in lower case not included in model 36b. Deposit with asterisk was excluded from grade and tonnage curves and descriptive statistics because it is an outlier in Au grade vs. tonnage plot.

Deposit	country	tonnage	Au grade	Ag grade	comments
Agnico-Eagle	CNQU	6,838,870	6.7	0	production plus reserves, 1989, Simard and Genest (1990)
BOB*	ZIMB	20,000	1.6	0	
Bousquet-Ellison-Dumagami	CNQU	13,765,444	5.5	0.27	production and reserves, 1987; Marquis and others (1990)
Bugow	CNNT	152,000	8	0	indicated, weighted average grade, Gibbins and others (1991)
Butterfly	CNNT	127,000	16	0	indicated, Gibbins and others (1991)
Camperdown-Red Hill	ZIMB	3,065,789	1.9	0	production to 1977, Foster and others (1986)
Carshaw-Malga	CNON	***247,000***	***7.5***	0	Fyon and others (1983)
CENTRAL PATRICIA	CNON	***1,520,000***	***12.5***	1.15	resources, Fyon and others (1992)
COONEMARA	ZIMB	***3,397,347***	***4.9***	0	production to 1977, Foster and others (1986)
COPPERHEAD	AUWA	***4,117,219***	***5.17***	0	production to 1987 plus reserves June, 1987, Woodall (1990)
Doyon	CNQU	25,242,864	5.5	0	production and reserves, 1987; Marquis and others (1990)
Giant	ZIMB	2,121,707	8.2	0	production to 1977, Foster and others (1986)
HARDROCK-MCLEOD-COCKSHUTT	CNON	16,560,200	5.3	0.3	
Hill 50 (Mount Magnet)	AUWA	7,754,727	7.94	0	production to 1987 plus reserves June, 1987, Woodall (1990)
HOMESTAKE	USSD	147,700,000	8.38	2.06	
Jardine	USMT	1,600,000	8.8	1.5	written communication, J. Hammarstrom (1994)
Lady Lina	ZIMB	132,843	10.2	0	production to 1987 plus reserves June, 1987, Woodall (1990)
LANCEFIELD	AUWA	***6,376,406***	***8.17***	0	production to 1987 plus reserves June, 1987, Woodall (1990)
Lupin	CNNT	8,220,183	10.7	0	Gibbins and others (1991)
Morning Star et al (Mount Magnet)	AUWA	8,142,806	3.75	0	production to 1987 plus reserves June, 1987, Woodall (1990)
MORRO VELHO	BRZL	13,350,000	17	0	
Nevoria	AUWA	7,168,091	3.17	0	production to 1987 plus reserves June, 1987, Woodall (1990)
PICKLE CROW	CNON	2,969,720	15.4	1.79	
RAPOSOS	BRZL	3,395,000	9.5	0.29	
Sherwood Starr	ZIMB	1,840,125	8	0	production to 1977, Foster and others (1986)
Starra	AUQL	5,300,000	5.3	0	Davidson and others (1989)
Torp Lake	CNNT	490,000	10	0	indicated, Gibbins and others (1991)
Vubachikwe	ZIMB	2,091,528	7.2	0	production to 1977, Foster and others (1986)
Wanderer Group	ZIMB	8,878,780	4.1	0	production to 1977, Foster and others (1986)
Watertank Hill-St. George-Hill 60	AUWA	1,701,221	5	0	production to 1987 plus reserves June, 1987, Woodall (1990)
WESTFALIA-MOUNT MORGANS	AUWA	***1,987,793***	***8.91***	0	production to 1987 plus reserves June, 1987, Woodall (1990)

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