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Preliminary Grade and Volume Model of Alluvial Sn-Au Placers

by

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Summary

The following preliminary points are made during this study of Sn-Au placer deposits:

- Grade and volume model of Sn-Au placers is developed from 63 deposits found worldwide

- The model is preliminary because:
  (1) it includes some highly uncertain data,
  (2) most S.E. Asia deposits are absent,
  (3) significant departure from the expected lognormal distribution in volume is found, and
  (4) data are from deposits worked using small-volume and large-volume methods

- The model is for use in mineral resource assessment

- Sn grades and deposit volumes are not significantly correlated (fig. 1)

- The volume of Sn-Au placer deposits is extremely variable--80 percent of the deposits have volumes between 8,800 m^3 and 91 million m^3 (fig. 2)

- 80 percent of the deposits have Sn grades between 0.15 and 2.5 kg/m^3 (fig. 3)

- Gold grades are reported in 15 percent of the deposits

- There is one chance out of ten the gold grade is greater than 4.5 g/m^3 (fig. 4)

Introduction

Placer deposits have been, and continue to be, the main source of Sn in the world. The only Sn production within the United States from 1990 to 1994 was from placers in Alaska; the amount was negligible (Carlin, 1995). Sainsbury and Reed (1973) suggest that nearly all other tin production in North American was a byproduct of lead-zinc production (Sullivan, British Columbia), molybdenum production (Climax, Colorado), and silver production (San Antonio mine, Mexico). More than one-sixth of the tin consumed in 1994 in the United States was recovered from old scrap (Carlin, 1995). Most of the production of, and identified resources for Sn are in China, Brazil, Malaysia, Thailand, and Indonesia (Carlin, 1995; Sutphin and others, 1990). Much of this is in placer deposits.

The grade and tonnage model like the one given here is for use in mineral resource assessment (Singer, 1993). See Cox and Singer (1986) for a large collection of examples of grade and tonnage models. This is the first attempt to prepare a grade and tonnage model of Sn placers, an important deposit type.

Geology

Sn placers develop because Sn, commonly cassiterite, is resistant to weathering, and has a high specific gravity. Eluvial deposits develop when cassiterite-rich bedrocks are chemically weathered with little transport. Cassiterite, along with other heavy minerals, can also concentrate in stream bottom gravel as alluvial placers. Some cassiterite can be trapped in bedrock including natural riffles, potholes, and other features that cross obliquely to the direction of stream flow. Economic Sn placers are usually found within 8 km of the bedrock source (Reed, 1986). Streams flowing parallel to contacts of tin-bearing granites with country rock have a greater likelihood of developing Sn placers (Reed, 1986). No particular size or grade relation is observed between the bedrock sources and placer deposits. Reed (1986, p. 275) describes the tectonic setting as one "derived from Paleozoic to Cenozoic accreted terranes or stable craton foldbelts that contain highly evolved granitoid plutons or their extrusive equivalents." Reed (1986) lists some minerals commonly associated with cassiterite which include magnetite, ilmenite, zircon, monazite, allanite, xenotime, tourmaline, columbite-tantalite, garnet, rutile, and topaz. Other commodities (metals, minerals, and gemstones) noted during data compilation includes gold, tungstite, corundum (including sapphires), diamonds, spinel, and quartz (including citrine, and amethyst), and chalcedony (including agate). Some of these commodities are recovered but most reporting lacks grade data. For example, imenite is an important byproduct commodity in S.E. Asia where heavy mineral byproducts are traditionally called "amang." Production of ilmenite from Sn placers has be so large in Malaysia that it has made the country at times a world class producer of the commodity (Force, 1976).

Most alluvial Sn-Au placers are Quaternary; a few are Tertiary. Deposits can include glacial-fluvial alluvium (Argentina, Bolivia), river beds, terraces, and colluvium (West Australia), however most are non-glacial alluvial deposits. Those worked by ocean dredges in Southeast Asia are flooded subaerial alluvial deposits. Some placer deposits in Bolivia were developed from Sn contributed by old mill tailings, smelter wastes associated with previously worked lode mines, and some from erosion of old placer tailings.

Problems in modeling placers

Data were not previously available to allow preparation of a grade and tonnage model for publication with the descriptive model of alluvial placer Sn (Reed, 1986). Collecting grade and volume data of sufficient quality for modeling all types of placer deposits are difficult. Uncertainty in basic data on placers can vary from moderate to extreme. This clearly was true in this study. Compiling a large data set (that is, one with hundreds of deposits) minimizes the impact of poor quality data (Orris and Bliss, 1985) but was not possible for Sn placers. Few alluvial Sn placer deposits were found with sufficient reporting to develop useable data. The resulting model is comparable in one way to the first model developed for Au-PGE placers by Orris and Bliss (1986)--large variance in deposit size is present which is not typical of most grade and tonnage models (Singer, 1986).

Mixing data from different mining methods can also result in large variances.

Deposits we used range from those worked by a few miners using primitive mining methods to extract Sn from a small body of alluvium along a stream to those worked by large floating ladder dredges with sophisticated extraction circuitry working scattered mineralized bodies on the ocean floor. Drift (underground) mining has also been used to work rich Sn horizons in some deposits. A deposit can be worked by both small-scale surface mining and drift mining, and subsequently undergo large-scale dredging. Both deposit size and Sn grade (as well as cutoff grade) are effected by mining method. The variability in deposit size of placers can be reduced by modeling groups of data classified by mining method (Bliss and others, 1987). This was possible for Au placers because a large data set was available. The small data set for Sn-Au alluvial placers makes this an approach impossible.

Data

Alluvial Sn-Au placers within 1.5 km of each other were combined to form deposits. Some have workings of unknown spacing. Basic data for deposits considered for use in modeling are shown in the Appendix. Some deposit volumes and commodity grades contain substantial uncertainty; they may be useable in modeling but probably not for other uses. Geologic and other basic data of most of the deposits are found in the Mineral Resource Data System (MRDS), a computerized database on mineral resource operated by the USGS. Greta Orris kindly provided some of the data for several deposits found in Southeast Asia.

Model

This model is the companion grade and volume model to accompany the descriptive model of alluvial placer Sn by Reed (1986). For placer deposits, volume, not tonnage, is the preferred measure of deposit sizes. The deposit type name includes Au as it is an occasionally reported byproduct. Some, but not necessarily all of the gold is likely from different bedrock sources than the Sn and its inclusion here is partly an artifact of reporting. The addition of Au to the model title simply reminds users that the contribution of Au can be forecast for Sn placers during mineral resource assessment. E.R. Force (written commun., 1995) suggests a number of other commodities might be part of the name if consideration is given of other heavy minerals likely found in the bedrocks sources of Sn. This includes ilmenite (which should be present in deposits from S.E. Asia--15 percent of the model deposits) or columbite-tantalite which is perhaps the most closely related to Sn (E.R. Force, written commun., 1995).

A scatter plot (fig. 1) shows Sn grades to be independent of placer volumes. The volumes and Sn grades are not significantly correlated at the 1-percent confidence level. The skewness and kurtosis goodness-of-fit tests (Rock, 1988) lead to the rejection the use of a lognormal distribution at the l-percent confidence level as suitable to characterize deposit volume. The divergence from lognormality may be due to the several issues noted on the previous section on problems in modeling placers. Therefore, the percentiles (90th, 50th, and 10th) in figure 2 are for the data and not for a fitted distribution as in the Sn grade model (fig. 3). The skewness and kurtosis goodness-of-fit tests (Rock, 1988) fail to provide reasons to reject the use of a lognormal distribution at the l-percent confidence level to characterize Sn grade data.

Gold, the most frequently reported commodity besides Sn, has been recovered from some of these placer deposits and is part of this model. Placer deposits rarely contain just one commodity. Some deposits, in particular, those with other commodities in recoverable concentrations, can produce several commodities. The model of Au grades is truncated (fig. 4) because only 15 percent of the deposits used in modeling have reported gold grades.

Closing Remarks

The model of Sn-Au alluvial placers is for used in mineral resource assessment as outlined by Singer (1993). Although the model is preliminary, it can still be used. The model is preliminary because of large uncertainties in some of the data values. The use of data from deposits worked using small-scale and large-scale mining methods adds further uncertainty and probably contributed to to the rejection of the lognormal distribution; dividing the data by mining method will help reduce the variability but the data set is currently too small to do this. Some variability may also be found by mixing reported values with estimated values. Uncertainty is unavoidable in grade and volume modeling; it can only be reduced, not eliminated.

How representative the model is of all Sn-Au placers is unclear. Both data and details necessary to define many deposits in S.E. Asia were either few or absent. Data are reported by country or region only. The grade and volume model may be improved, however, to do so will require further basic data which are difficult to develop.

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Appendix. Basic data used for modeling alluvial Sn-Au placer deposits. Data sets are never complete or without errors despite efforts to make them so. Additions and corrections are welcome and can be sent to Jim Bliss, U.S. Geological Survey, 210 E. 7th St., Tucson, AZ 85705-8454, U.S.A. Abbreviations used for countries (some giving internal political subdivision thereof) are as follows: AFGH--Afganistan; ARGT---Argentina; AUNS--New South Wales, Australia; AUQL--Queenlands, Australia; AUTS--Tasmania, Austrialia; AUVT--Victoria, Austrialia; AUWA--West Austrialia, Australia; BLVA--Bolivia; BRZL--Brazil: INDO--Indonesia; MLYS--Malaysia; MYLA--Myanmar; NGRA--Nigeria; SWAZ--Swaziland; THLD--Thailand; UKEN--United Kingdom, England; and USAK--United States, Alaska. Data are for use in modeling and may not be suitable for other uses.

Deposit Name	Country Abbrev.	Volume (10^6 m^3)	Sn (kg/m^3)	Au (g/m^3)
Anana	BRZL	0.012	0.920	
Ban Bo Kaew	THLD	3.11	0.610	
Bangka Island (P.T. Koba Tin)	INDO	79.2	0.700	
Battle Creek	AUQL	14	0.230	
Beechworth-Eldorado	AUVT	72	0.087	0.3
Belitung Island (P.T.Tambang Tinah)	INDO	27.3	0.210	
Binneringie eluvials	AUWA	0.011	0.170	
Brascan	BRZL	17.2	0.840	
Briseis Mine-Clifton Lead	AUTS	34	0.600	
Buck Creek	USAK	0.59	1.700	
Buckeen Creek	AUNS	0.00033	3.500	
Burra Creek	AUNS	0.017	0.510	12
Cape Creek Area	USAK	1.4	0.570	
Cassiterite Creek	USAK	0.04	2.100	
Chockopampa	BLVA	0.033	3.400	
Coondina	AUWA	1.4	0.730	
Cuajong	AUNS	0.0082	1.000	
Dalton Creek	USAK	0.0016	0.850	8.9
Deep Creek-Woodchopper Creek	USAK	0.0645	0.500	17
El Centenario	BLVA	89.5	0.248	
Five Mule Creek	AUWA	0.01	0.610	
Friendly Creek	AUWA	1.1	0.460	
Gibsonvale	AUNS	0.91	6.060	

Great Northern Plain	AUTS	6.16	0.140	
Greenbushes	AUWA	28.1	0.240	
Heinze Basin	MYLA	14.5	1.240	
Herberton	AUQL	57.8	0.160	
Jos Plateau	NGRA	270	0.029	
Kinta Valley	MLYS	1900	0.640	
Koetong	AUVT	0.54	0.220	
Kuala Langat	MLYS	245	0.190	
Laboo	THLD	9.2	1.600	
Lipez Huayeo-Antequera	BLVA	37	0.420	
Mason Creek	USAK	0.014	0.350	1.6
McCreedy Tin	SWAZ	0.14	0.280	
Moolyella Tin Field	AUWA	3.2	2.400	
Mount Pilot	AUNS	0.009	0.200	
Musgrave	AUNS	0.0046	0.700	
Nam Pathene	LAOS	12	4.600	
Nettle Creek	AUQL	8.8	0.300	
North Placers	AFGH	0.046	0.250	
Pilgangoora	AUWA	0.033	0.280	
Pinga Creek	AUWA	0.048	0.770	
Pioneer Lead	AUTS	6.4	0.890	
Pirquitas	ARGT	0.015	3.000	
Pitinga	BRZL	296	1.620	
Puhong	MLYS	2.9	0.659	
Return Creek	AUQL	26	0.180	
Rondonia Tin District	BRZL	1000	0.520	
San Francisco	BLVA	0.053	6.800	
San Vicente	BLVA	1.2	5.400	
Sandy Creek	AUNS	0.043	0.120	1.2
Shaw River Cooglegong	AUWA	4.1	0.680	
Shaw River Eleys	AUWA	1.3	0.860	
St. Ives Bay	UKEN	0.252	4.000	
Stannary Hills	AUQL	0.52	0.420	
Swamp Creek	AUNS	0.0045	0.560	
Tabba Tabba	AUWA	0.001	0.140	
Tinga	AUNS	49	1.000	
Tofty Area	USAK	1.2	0.190	6.4
Toora field	AUVT	0.14	1.840	0.023
Upper Basin Creek	AUNS	0.047	2.000	
Viloco	BLVA	100	0.100	96

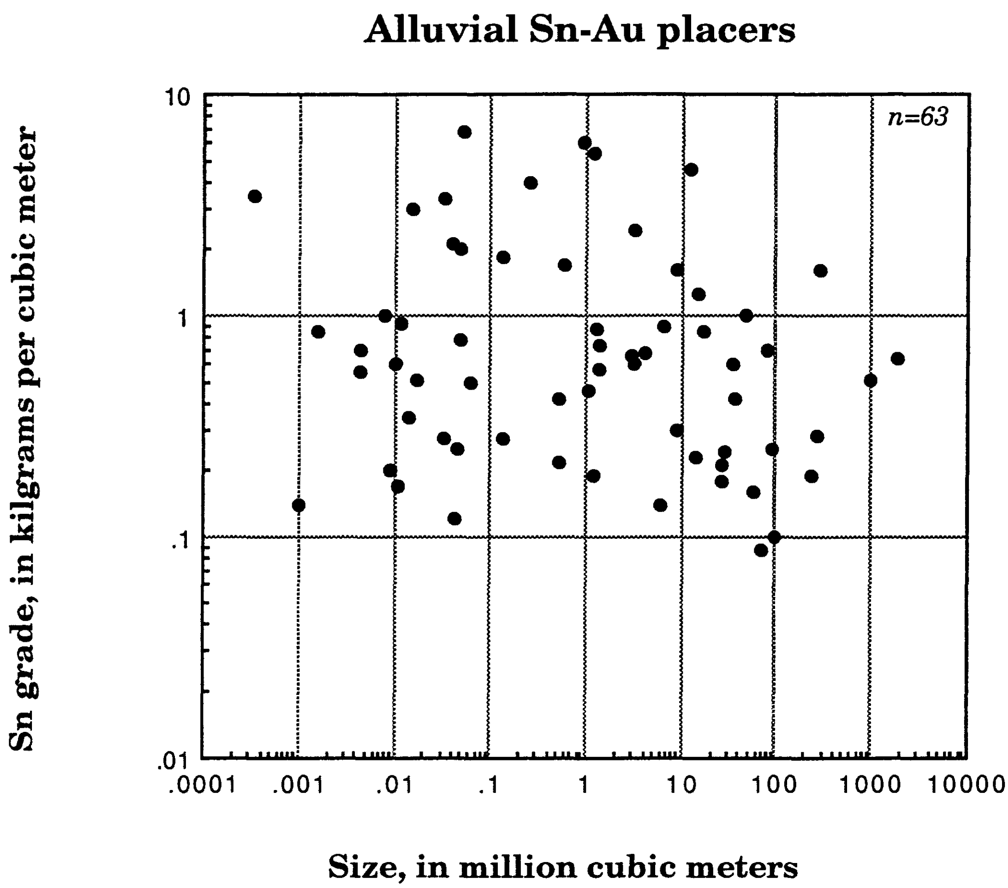

Figure 1. Scatter plot of Sn grades (in kilogams per cubic meter) and deposit sizes (in million cubic meters) of alluvial Sn-Ag placers.

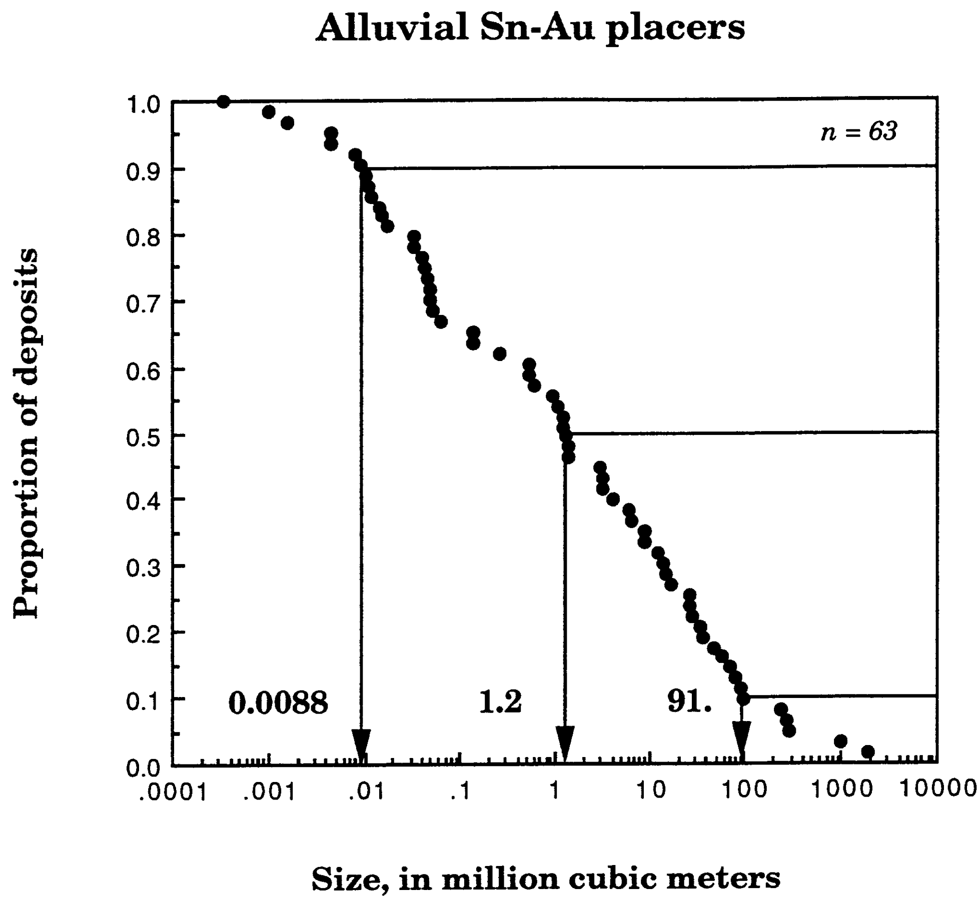

Figure 2. Deposit volumes (in million cubic meters) of alluvial Sn-Au placers.

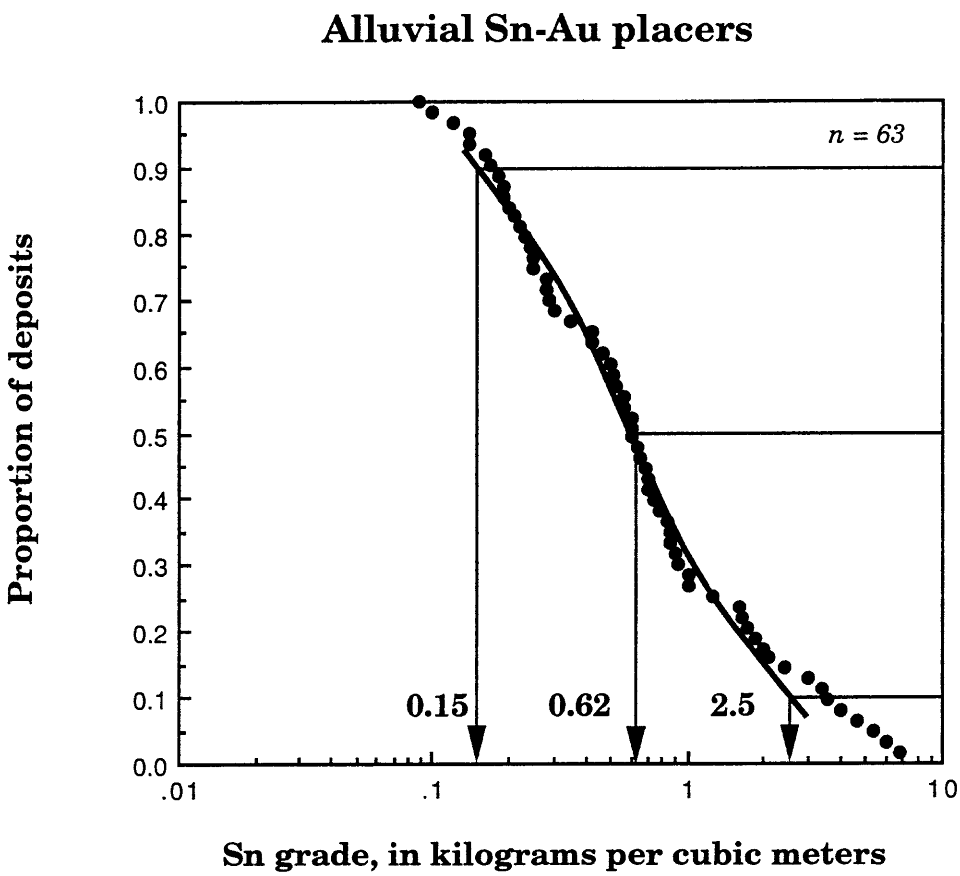

Figure 3. Sn grades (in kilograms per cubic meter) of alluvial Sn-Au placers.

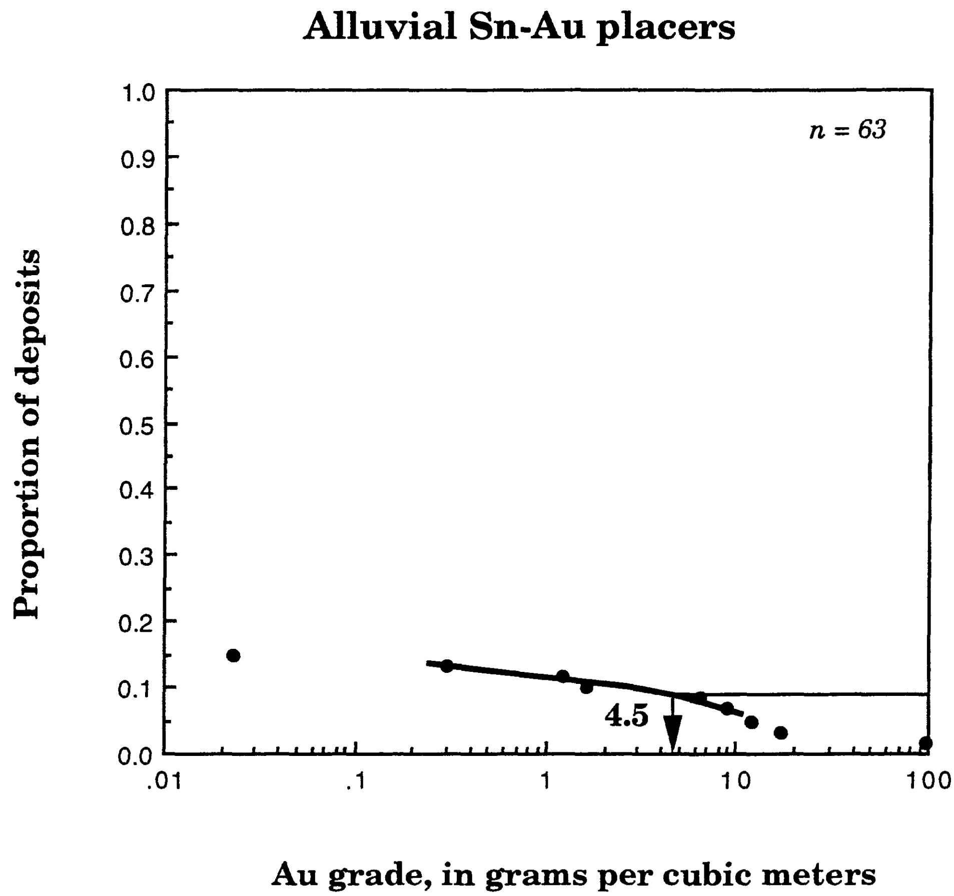

Figure 4. Au grades (in grams per cubic meter) of alluvial Sn-Au placers.