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Lacustrine Manganese

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Descriptive Model

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Grade-Tonnage Model

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Geophysical Model

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Model 40b

DESCRIPTIVE MODEL OF LACUSTRINE MANGANESE

by

Keith R. Long

BRIEF DESCRIPTION

DESCRIPTION: Bedded and vein manganese oxide deposits in sediments and volcanics filling half-graben basins associated with detachment faulting.

TYPICAL DEPOSITS: Aguila, AZ (Allen, 1985), Artillery, AZ (Lasky and Weber, 1949; Spencer and others, 1989), Virgin River, NV (McKelvey and others, 1949)

COMMODITIES: Mn

OTHER COMMODITIES: Pb-Cu-Fe-Ag-Au-Ba-Sr-As-U

ASSOCIATED DEPOSIT TYPES (*suspected to be genetically related):
*Detachment-fault-related polymetallic deposits

REGIONAL GEOLOGIC ATTRIBUTES

TECTONOSTRATIGRAPHIC SETTING: Extensional terranes characterized by regional detachment faulting.

REGIONAL DEPOSITIONAL ENVIRONMENT: Hydrographically-closed, half-graben basins formed as a result of detachment faulting.

AGE RANGE: Known stratiform deposits are Miocene in age. Vein deposits are several million years younger than stratiform deposits.

LOCAL GEOLOGIC ATTRIBUTES

HOST ROCKS: Interbedded Tertiary volcanoclastic sandstone, conglomerate and mafic extrusive rocks deposited in lacustrine to alluvial fan environments.

ASSOCIATED ROCKS: Tertiary silicic volcanic rocks and lacustrine sediments.

ORE MINERALOGY: Manganese oxides (usually hollandite, coronadite, todorokite, cryptomelane, pyrolusite; locally manganite; rarely ramsdellite, neotocite).

GANGUE MINERALS: Manganiferous calcite ± quartz ± gypsum. Locally barite and fluorite.

ORE CONTROLS: Veins are found in high angle faults stratigraphically below bedded deposits. Stratified deposits are inferred to be localized at or near the intersection of these faults with the paleosurface. Largest deposits are found at the intersection of high angle faults.

ISOTOPIC SIGNATURES: Data (Bouse and others, 1987) on lead isotopes (17.4-19.3 $^{206/204}Pb$; 15.5-15.6 $^{207/204}Pb$; 38.1-39.9 $^{208/205}Pb$) indicate that in some districts Mn and other metals were derived from Proterozoic and Mesozoic basement rocks, and in other districts from Tertiary cover rocks. Isotopic values for gangue gypsum (0.71005-0.71146 $^{87/86}Sr$; 12.6-14.1 $\delta^{34}S$) indicate deposition in a nonmarine environment. Data (Yeh and others, 1985) from gangue calcite (+15 $\delta^{18}O$ per mil; -2.4 to -1.6 $\delta^{13}C$ per mil) and manganese oxides (-9.8 to +0.9 $\delta^{18}O$ per mil; -109 to -87 δD per mil) are consistent with low temperature (up to 200 °C) deposition from connate brines.

FLUID INCLUSIONS: Gangue minerals in vein deposits (Spencer and others, 1989; Spencer, 1991): quartz (4 inclusions) 165 to 170 °C, 1 to 1.75 weight percent equivalent NaCl; calcite (42 inclusions) 0 to 3.25 weight percent equivalent NaCl; barite (43 inclusions) 0 to 1.75 weight percent NaCl. Evidence of boiling. Fluids were probably oxidized.

STRUCTURAL SETTING: High-angle faults intersecting low- to medium-angle faults within the upper-plate of a detachment-fault system.

ORE DEPOSIT GEOMETRY: Veins are 0.3 to 5 meters wide and have strike lengths of 15 to 330 meters. Bedded deposits are 4 to 18 meters thick and 300 to 1500 by 180 to 720 meters in areal extent.

ALTERATION: Very localized silicification adjacent to veins. Pre-ore (?) K-metasomatism of associated volcanic and volcanoclastic rocks. Mafic rocks are converted into K-feldspar-hematite-calcite-chlorite-epidote rock, silicic rocks into K-feldspar-hematite-quartz rock.

TYPICAL ALTERATION/OTHER HALO DIMENSIONS: Silicification is very narrow. K-metasomatism is regional in extent.

EFFECT OF WEATHERING: Alteration of manganese oxides to hydrous manganese oxide (wad). Supergene enrichment can occur resulting in replacement of gangue by

opal and calcite and reconstitution of Mn minerals as manganite and "psilomelane."

EFFECT OF METAMORPHISM: Metamorphosed lacustrine manganese deposits are not known. Other types of sedimentary manganese-oxide deposits when metamorphosed are generally reconstituted (in the absence of iron oxides) to high-temperature, lower-oxide assemblages including bixbyite, hollandite, and hausmannite (Roy, 1981).

GEOCHEMICAL SIGNATURE: The association of Mn with Ba, Pb, Ag, As, and other anomalous trace elements in these ores may serve as a useful geochemical exploration tool.

GEOPHYSICAL SIGNATURE: Specific gravity of ore: 1.2-2.2 (primary), 2.5-3.1 (supergene enriched). Treating the Mn ores as a facies change within the host sediments, resistivity and high-resolution seismic reflection techniques may be useful. Despite their low grade, there may be sufficient density contrast between Mn ore and host sediments for microgravity techniques to be useful. Some multispectral airborne radiometric methods might be useful for mapping surface outcrops of Mn ore. The U content of Mn ore may be sufficient to yield a radioelement contrast with the host rock.

OTHER EXPLORATION GUIDES: An understanding of basin geometry and history, and of the distribution of lacustrine facies and intersecting high-angle faults are useful regional exploration guides.

OVERBURDEN: For known deposits, generally thin to absent. Deposits could occur anywhere within the host basin, which are up to a kilometer or so deep.

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GRADE-TONNAGE MODEL OF LACUSTRINE MANGANESE

by

Keith R. Long

All known lacustrine manganese deposits occur within southernmost Nevada, western Arizona, and southeastern California. Grade and tonnage data have been published for only six of the dozen or so known deposits (Table 1). These data are fit very poorly by the lognormal distribution (Figures 1 and 2), but this may be an artifact of the small sample size. Empirical distribution functions (EDF) for size and grade are plotted in Figures 3 and 4. The EDF is defined as :

$$F_n(x_n|x_1,\ldots,x_{n-1}) = \frac{n-1}{N}$$

where N is sample size and n is the nth sample value in order of increasing size. The relative frequencies defined by the EDF are the values for proportion of deposits plotted against deposit size and grade in Figures 3 and 4.

The median and percentiles for the fitted lognormal distribution, the empirical distribution function, and the sample median and percentiles (Table 2) differ significantly. These discrepancies strongly suggest that neither the fitted lognormal distribution nor the EDF are stable, in the sense that additional data would significantly affect the computed median and percentile values. Although the EDF may be preferred in this context because of the poor fit of the lognormal distribution, use of the EDF to represent the size and grade distribution of known or undiscovered deposits should be qualified to reflect the imprecision and instability of the EDF median and percentile values.

Table 1. Tonnages and grades for lacustrine manganese deposits. Sources: 1 (U.S. Bureau of Mines Yearbooks); 2 (Lasky and Webber, 1949); 3 (Lowe and others, 1985)

Deposit	Country	Tonnage Tonnes	Manganese Grade (percent)	Source
Aguila	USAZ	205,000	20.0	1
Artillery Peak	USAZ	180,000,000	4.0	2
Boulder City	USNV	14,000,000	3.0	3
Fannie Ryan	USNV	28,500	7.6	3
Three Kids	USNV	8,610,000	13.2	3
Virgin River	USNV	340,000	10.0	3

Table 2. Computed values for median and 10th and 90th percentiles for the size and Mn grade distribution for lacustrine manganese deposits according to (1) fitted lognormal distribution, (2) empirical distribution function, and (3) sample percentiles ($n/100$).

Tonnage (thousand metric tons)

Percentile	(1) lognormal	(2) EDF	(3) sample
10th	120,000	500,000	180,000
50th	1,900	8,600	4,250
90th	29	40	28.5

Mn Grade (percent)

Percentile	(1) lognormal	(2) EDF	(3) sample
10th	18.0	27.0	20.0
50th	9.6	10.0	8.8
90th	1.4	3.2	3.0

Figure 1. Tonnages of lacustrine manganese deposits fitted to a lognormal distribution.

Figure 2. Manganese grades of lacustrine manganese deposits fitted to a lognormal distribution.

Figure 3. Empirical distribution function for tonnages of lacustrine manganese deposits. Note that the complement $1-F_n(x)$ has been plotted to conform with the usual convention for tonnage models.

Figure 4. Empirical distribution function for manganese grades of lacustrine manganese deposits. Note that the complement $1-F_n(x)$ has been plotted to conform with the usual convention for grade models.

FIGURE 1

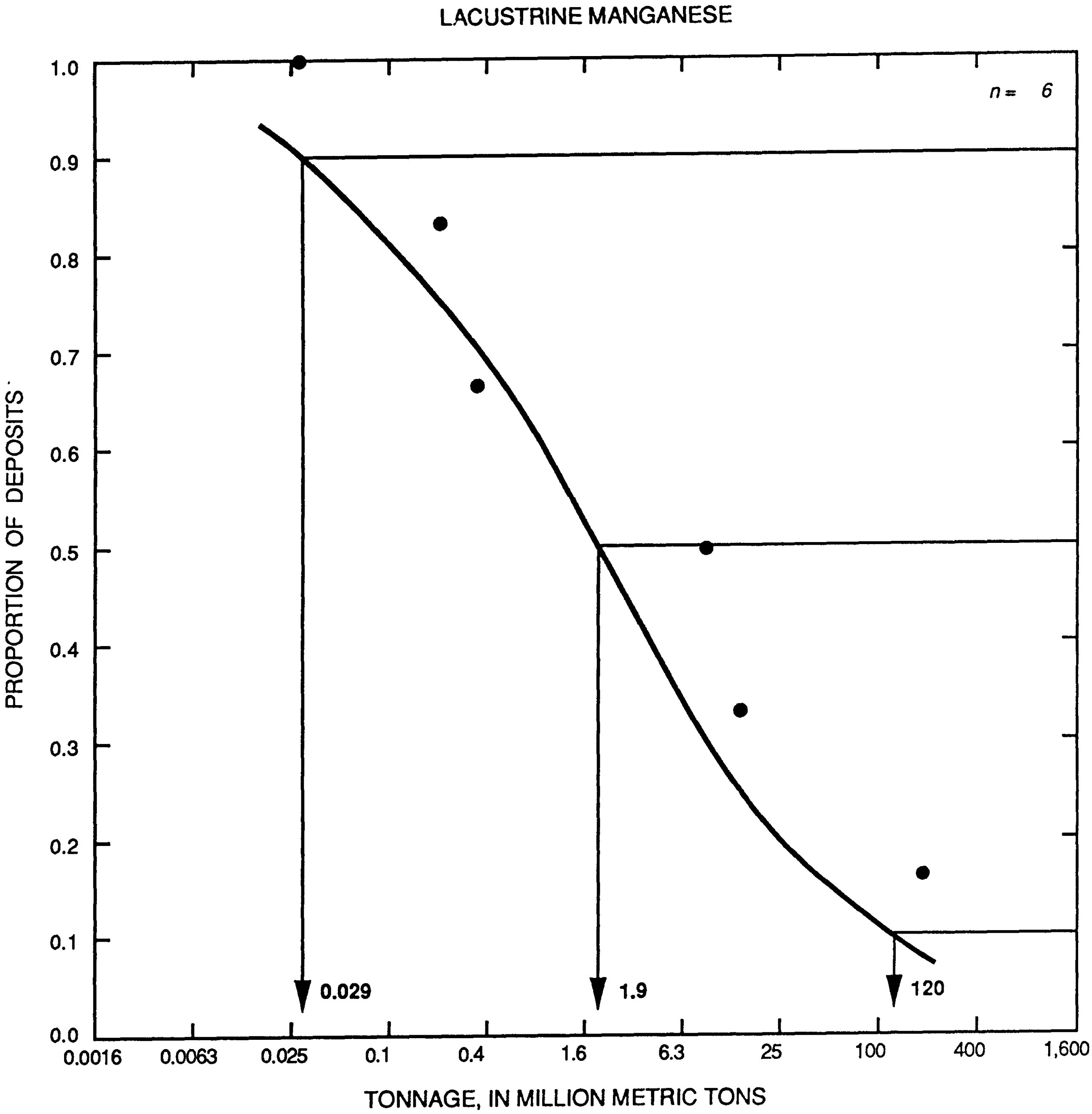

LACUSTRINE MANGANESE
n = 6
PROPORTION OF DEPOSITS
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.029
1.9
120
0.0016
0.0063
0.025
0.1
0.4
1.6
6.3
25
100
400
1,600
TONNAGE, IN MILLION METRIC TONS

FIGURE 2

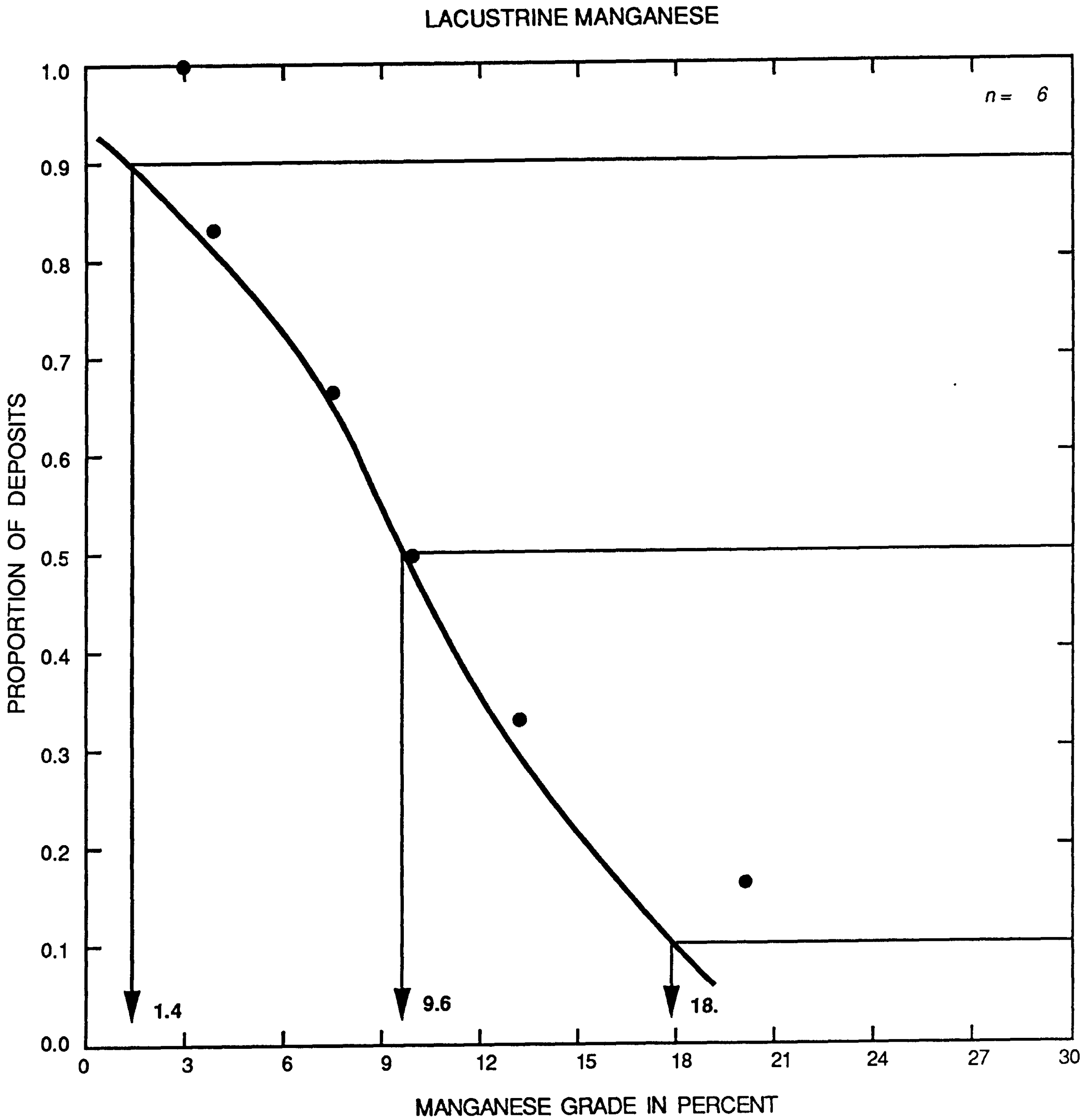

LACUSTRINE MANGANESE
n = 6
PROPORTION OF DEPOSITS
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1.4
9.6
18.
0
3
6
9
12
15
18
21
24
27
30
MANGANESE GRADE IN PERCENT

FIGURE 3

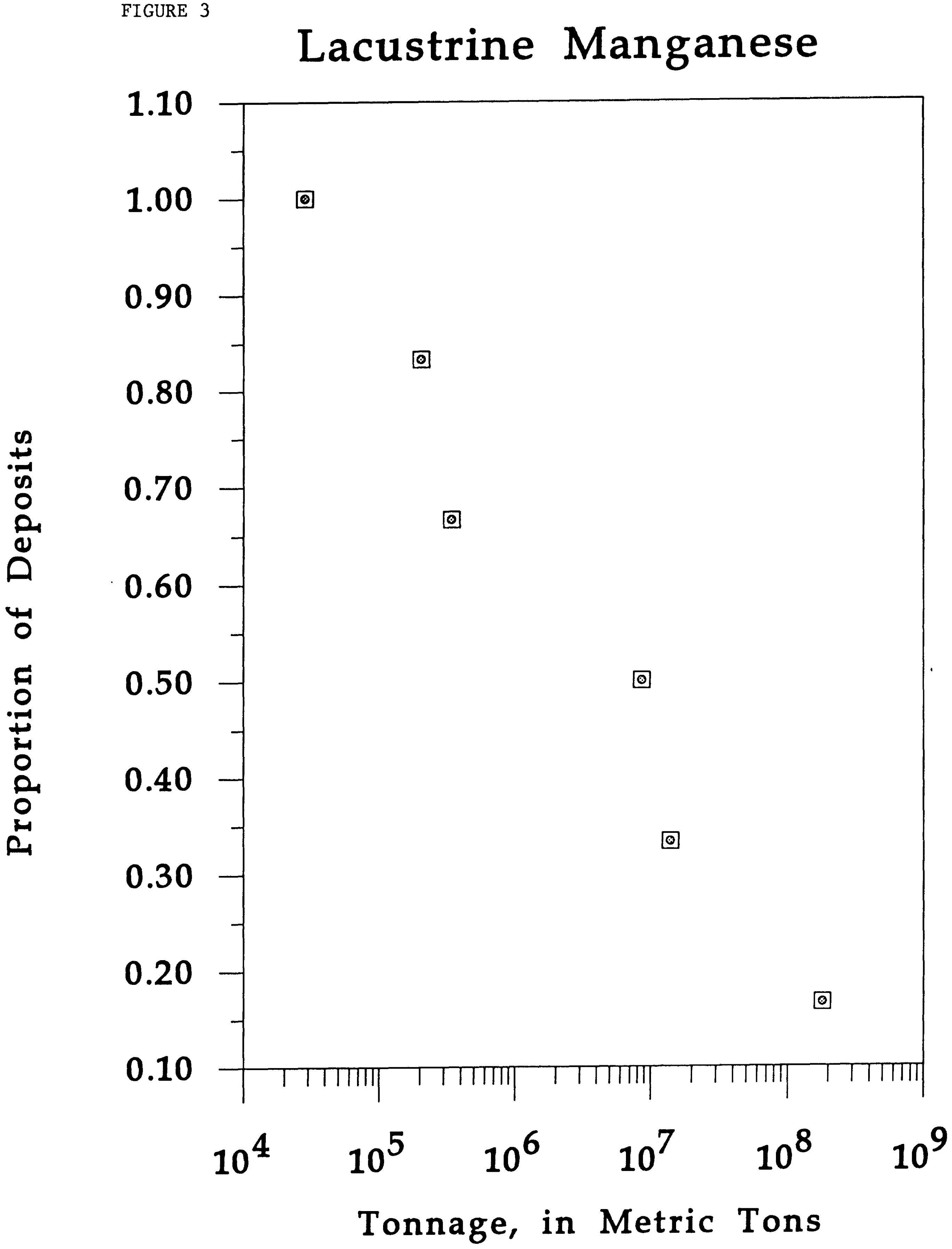
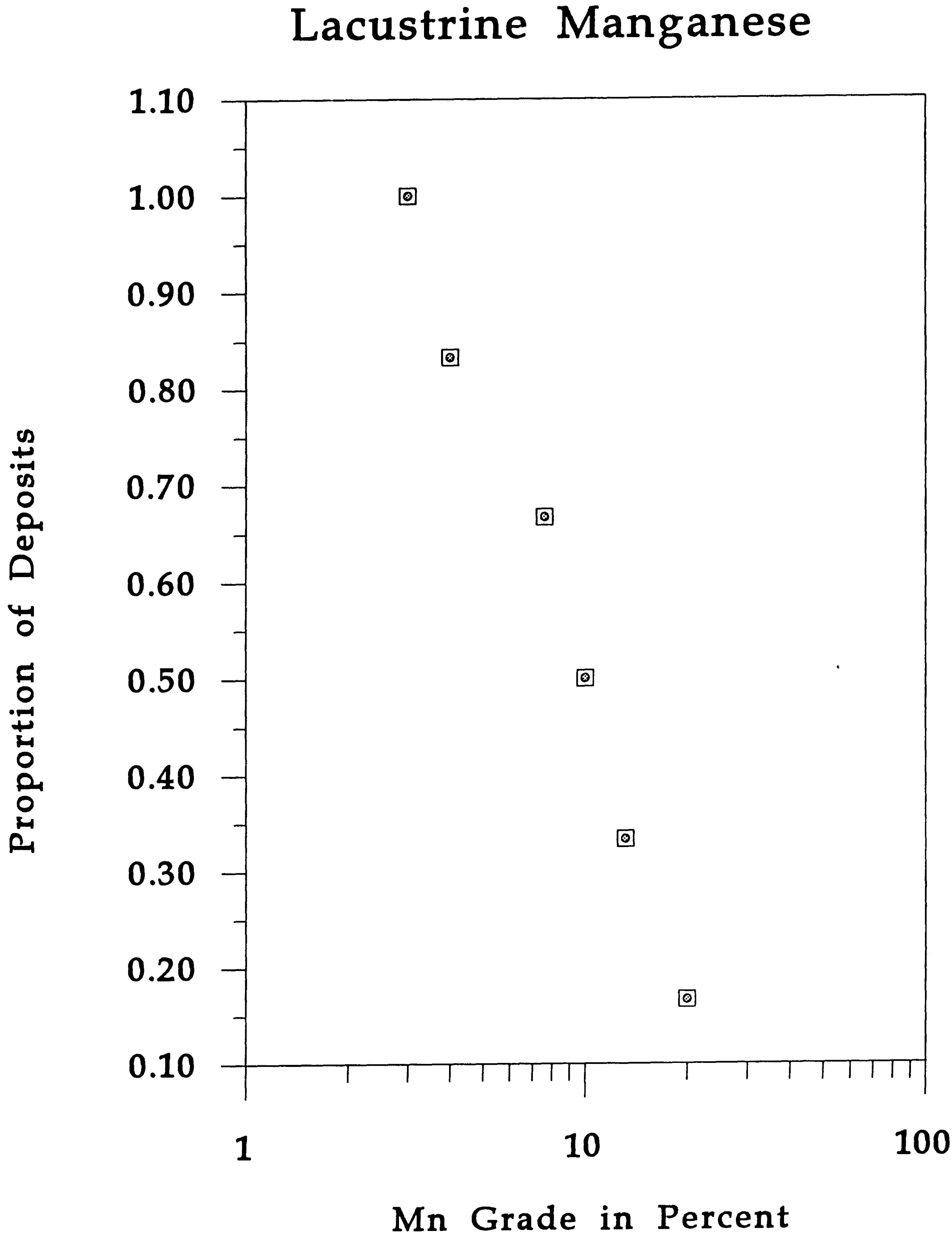

Lacustrine Manganese
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
Proportion of Deposits
10^4
10^5
10^6
10^7
10^8
10^9
Tonnage, in Metric Tons

FIGURE 4


Lacustrine Manganese
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
Proportion of Deposits
1
10
100
Mn Grade in Percent

Model 40b

GEOPHYSICAL MODEL OF LACUSTRINE MANGANESE

by

J.C. Wynn, F. Fritz, and J. Corbett

MORPHOLOGY

DEPOSIT: Lensoid, up to 1500 meters long, 720 meters wide, and 18 meters thick.

ALTERATION HALO: None.

CAP: Thin to absent overburden of lacustrine sediments.

PHYSICAL PROPERTIES

DENSITY: Primary ore: 1.2 to 2.2 g/cm^3, supergene enriched ore: 2.5 to 3.1 g/cm^3; pure manganese oxides: 4.8 to 5.1 g/cm^3.

POROSITY: Not reported in literature.

SUSCEPTIBILITY: Manganese oxides: 132 to 370 x 10^{-6} emu/cm^3.

REMNANCE: Not applicable.

RESISTIVITY: Manganese oxides: 0.002 to 0.5 ohm-m.

CHARGEABILITY: None reported in literature; probably negligible.

SEISMIC VELOCITY: None reported in literature; probably highly dependant upon mineralogy and depth of burial.

RADIOELEMENTS: Ores may contain uranium.

SPECTRALLY DETECTABLE MINERALS: Manganse oxides have high albedo in visible wavelengths.

GEOPHYSICAL EXPRESSION

DIRECT: Possible high resistivity contrast of manganse oxides interlayered with conductive sediments.

INDIRECT: Possible chargeability of associated sulfide minerals.

DIAGNOSTIC: Probably Time Domain Electro-Magnetic resistivity methods for both horizontal and vertical targets. Possibly microgravity and IP.

COMMENTS: This is a difficult deposit type to model due to deposit geometry and the poorly-documented physical properties of the manganese ores.

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