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ARTICLE

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Pb-Zn "SEDEX" deposits and their copper stockwork roots, western Cuba

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Abstract Base metal deposits in western Cuba belong to the SEDEX type, as defined by Carne and Cathro (1982). The age of the mineralisation is Jurassic. The host rocks of the deposits are gritstones, sandstones and black shales, with no igneous rocks involved. Sulphur isotopic data from pyrite and chalcopyrite indicate a biogenic and magmatic origin, at least for part of the Cuban sulphides. The inferred tectonic setting of these deposits is that of a passive continental margin. The Pb-Zn-Cu mineralisation in Cuba is hosted in the siliciclastic sedimentary rocks of the San Cayetano Formation (Lower-Upper Jurassic in age), which indicates derivation of quartzose grains from recycled orogen source areas, related to either the Grenville or Pan African granitic-metamorphic belts.

Introduction

This study describes the geology and inferred origins of the base metal deposits of Santa Lucia, La Esperanza, Castellanos and Matahambre in western Cuba (Figs. 1 and 2). They are grouped together in the Santa Lucia-Matahambre metallogenic district (Fig. 1), a term used in the sense of Gabelman (1976). As SEDEX deposits comprise over 50% of the world's Zn and Pb reserves, and are responsible for over 25% of world production (Goodfellow et al. 1991), the unusual character of the western Cuban deposits warrants investigation.

The discovery of the Matahambre copper deposit took place in 1912, when a farmer found rock fragments of a gossan on a hill top. Exploitation began in 1913, followed by a "copper rush" in the region. Since 1961, many exploration programs have been carried out for base metals and in 1970, the number 70 ore body (Pb-Zn) was discovered at Matahambre. Currently, copper exploitation continues, and in the Castellanos deposit, a gold open-pit was opened recently.

In this work, I discuss a classical SEDEX deposit model for the northwestern Cuban Pb-Zn deposits as proposed by Carne and Cathro (1982). The current syngenetic ore genesis model proposed here, and supported by most Cuban geologists, contrasts with earlier epigenetic models, which also suggested that the mineralization age was post-Upper Cretaceous or pre-Neogene (Tolkunov et al. 1974), and Upper Eocene (Laverov et al. 1967).

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General geological setting

The majority of SEDEX deposits formed in intracontinental rifts or in passive continental margin tectonic settings (Large 1980, 1983; Werner 1989, 1990; Goodfellow et al. 1991). SEDEX deposits are not reported from either magmatic arcs or in subduction zones; this is related to the scarcity of large coarse-turbidite sequences in these settings, as opposed to passive margins where they are common. Field evidence indicates only a single Jurassic magmatic arc on the island of Cuba, the Socorro Complex (Renne et al. 1989). The geotectonic setting for western Cuba, excluding the Bahia Honda terrane (an obduction zone), is that of a passive margin (Fig. 3), on a thin continental crust that belongs to the southern part of the North American plate (Simon 1987a). This passive margin began to form in the Lower Jurassic or before (Simon 1987b), with the breakup of Pangaea (known as the Reconquest Tethys in the Caribbean; Auboin 1977, in: Simon 1987a). The rate of accumulation of terrigenous sediments is high in a passive margin setting; there is a strong likelihood that the deposits of the Santa Lucia-Matahambre district were formed in such a setting.

Stratigraphic units: sedimentology, petrography and structural history

The Lower-Upper Jurassic San Cayetano Formation is the oldest formation in the region (Fig. 2). This approximately 3000 m thick

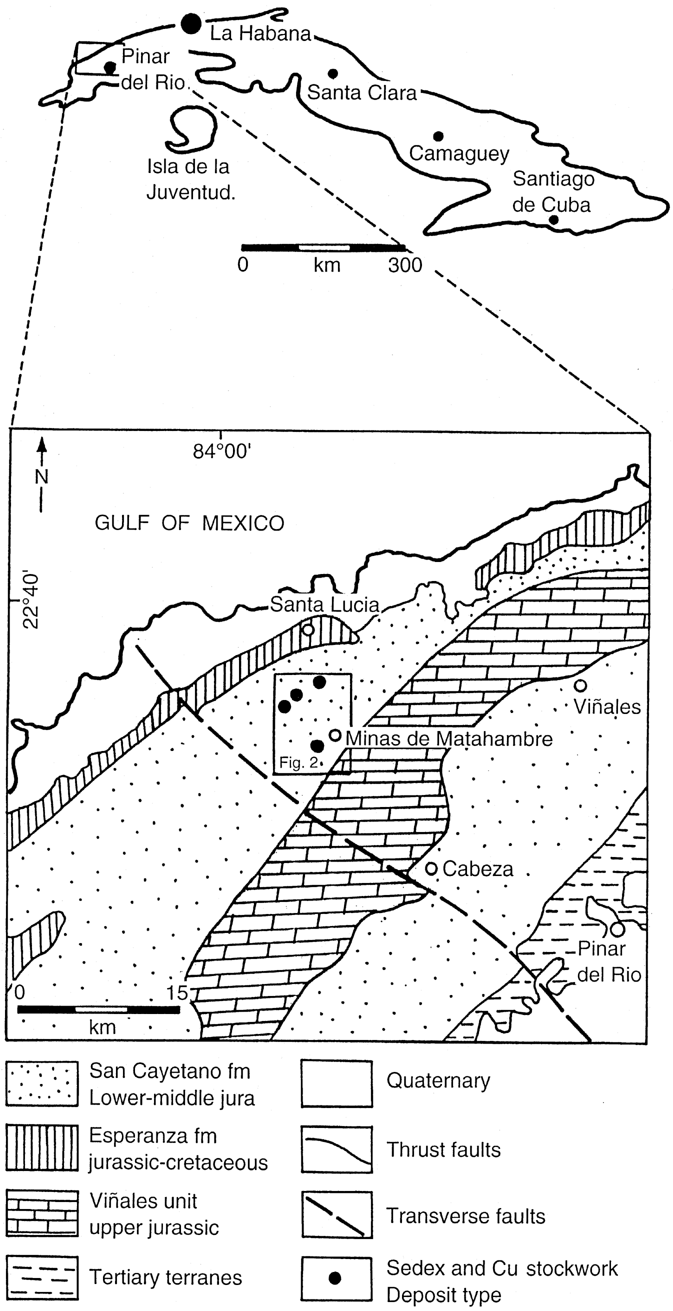

Fig. 1 Simplified geological map showing base metal deposits in western Cuba, and relevant geological terranes (after De Los Santos et al. 1988). Note location of *insert map* for Fig. 2

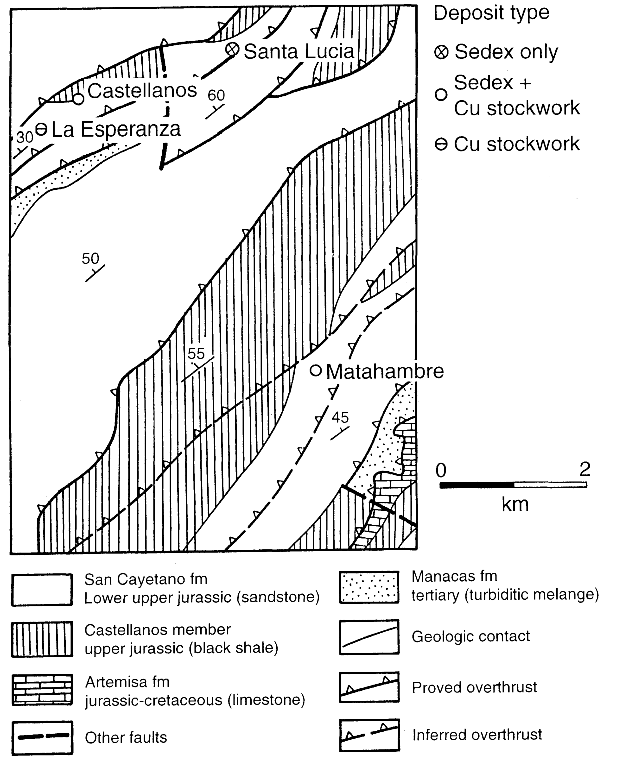

Fig. 2 Geological map of the Santa Lucia-Matahambre metallogenic district (after Empresa Geologo-Minera geological staff 1992, unpublished data)

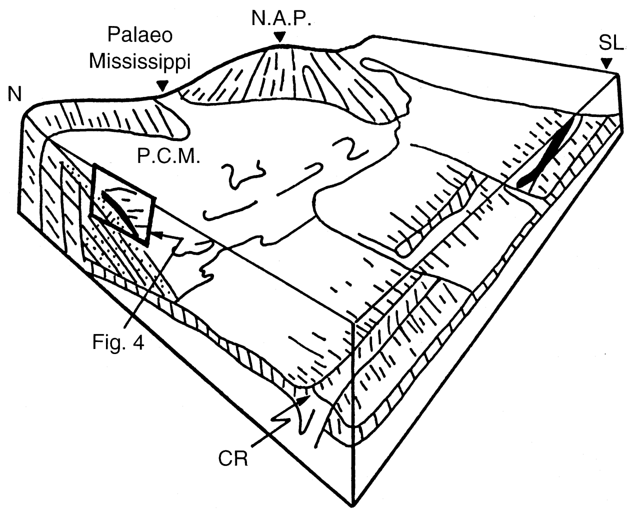

Fig. 3 Inferred geological setting of the Santa Lucia-Matahambre metallogenic district during the Jurassic (not to scale). *SL*, mean sea level; *NAP*, North American platform; *PCM*, passive continental margin, *CR*, Caribbean Rift. The *irregular*, *thick black line* denotes the possible location for the SEDEX deposits within the Cuban-Caribbean realm. Note location of *insert* for Fig. 4

unit was primarily defined by Bermudez (1961), and comprises thrusted sheets of sandstones, gritstones and minor black shales. Ripple marks and cross-bedding are common in the formation. The base of the formation is unknown. Mean composition of the San Cayetano Formation, determined from point-counting of 97 thin sections from footwall and hangingwall sandstones within the mineralised stockwork zones of the Matahambre deposit (ore bodies numbers 19–30 and 14–44), is: 95.8% quartz, 3.2% feldpsar and 1% lithic grains. These rocks are thus clearly quartz arenites, and when plotted on the tectonic setting ternary diagrams of Dickinson and Suczek (1979) and Dickinson (1985), indicate derivation of detritus from recycled orogenic source areas (Fig. 5). As can be seen from this figure, indicated provenance is the same for both footwall and hangingwall sandstones.

An upper, Castellanos Member, about 120 m thick and of Upper Jurassic age, consists essentially of black shales which form the top of the formation. This member has been the SEDEX horizon for decades of exploration, while the underlying San Caye-

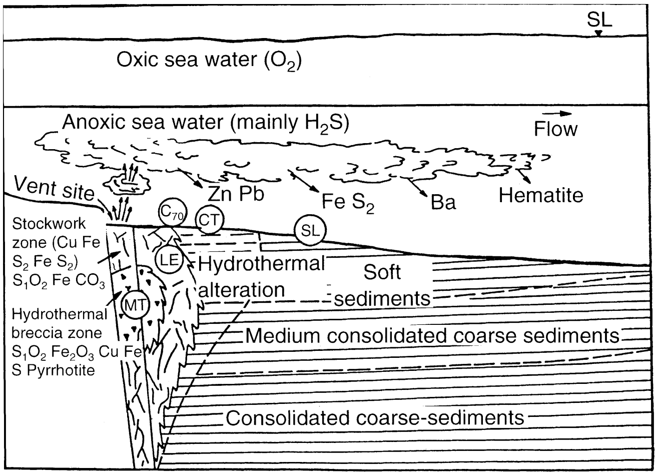

Fig. 4 Schematic cross-sectional model for the genesis of SEDEX Pb-Zn (barite) deposits, Selwyn Basin (after Goodfellow et al. 1991). Note the relationship of the Selwyn Basin model with the western Cuban deposits. *SL*, Santa Lucia; *C70*, polymetallic body number 70 (Matahambre deposit); *CT*, Catsellanos; *LE*, La Esperanza; *MT*, Matahambre Cu stockwork

tano sandstones host the associated Cu stockwork ores. Near the Pb-Zn ore bodies in the black shales, Fe-values are enhanced, and alkaline elements depleted.

There is consensus that the San Cayetano Formation was laid down within a deltaic-fluvial-fan palaeoenvironmental setting, situated on a passive continental margin. By floral analysis, the age is Callovian (Fig. 10). Sedimentation onto a thinned continental crust is thought to have begun in the Triassic, and ended in pre-Oxfordian times. Large rivers (Zhidkov and Jalturin 1976) are inferred to have deposited thousands of metres of sediment into a large rift basin. Towards the end of fluvial sedimentation, sediment loading-induced subsidence produced deeper water conditions suitable for black shale deposition in the uppermost, Castellanos Member.

Later, in the Cretaceous or Tertiary, collision of the Caribbean and North American plates led to folding and overthrusting, with the San Cayetano clastic sediments, and the Jurassic mineral deposits which they host, being displaced from south to north. The Castellanos Member black shales were also folded, became graphitic, and hydrothermal chloritisation and carbonitisation also occurred. The upper contact of this member with the overlying Artemisa Formation limestones comprises a major shear zone. Near these thrust faults, the Castellanos shales are brittle, and locally ductile. A melange-like association of blocks of Artemisa limestone within the Castellanos black shales is observed locally in this sheared contact zone.

The Upper Jurassic (Oxfordian – possibly Lower Cretaceous) Artemisa Formation overlies the San Cayetano Formation, above a thrusted contact. The former is about 400 m thick on average, and comprises essentially deep-water, micritic limestone. The upper contact is also characterised by thrust faults, above which is the Tertiary (Palaeogene) Manacas Formation. This unit, which is approximately 250 m thick, consists of a chaotic melange of blocks of sandstone, black shale, limestone, mafic rocks and serpentinites, within an argillitic-serpentinised matrix. This melange deposit, derived from the underlying formations, was a consequence of the collision between the Caribbean and North American plates.

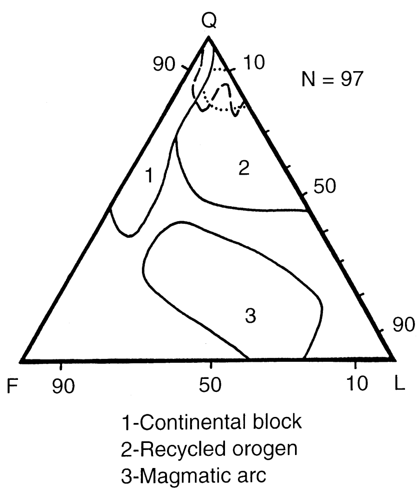

Fig. 5 Ternary diagrams for inferred source terrains of the sandstones hosting the Matahambre deposit. Fields after Dickinson and Suzcek (1979). *Dashed line*, field for Matahambre deposit sandstones which encompass the 19–30 Cu ore bodies; *dotted line*, field for Matahambre sandstones which encompass the 14–40 Cu ore bodies; *Q*, quartz; *F*, feldspar; *L*, lithic grains

Geology of the ore deposits

The general geology of the SEDEX and Cu stockwork deposits in western Cuba has been summarised by Zhidkov and Jalturin (1976) and Simon (1987a,b):

1. The host rocks to the mineralisation are fine-grained, terrigenous deltaic deposits of the San Cayetano Formation, comprising mainly gritstones, sandstones and black shales.
2. Igneous rocks are apparently absent within the mineralised succession.
3. The Pb-Zn ore bodies are concordant with the sedimentary bedding and are essentially stratiform. The Cu-pyrite stockwork roots are discordant and always underlie the Pb-Zn ores.
4. A common mineralisation age of Middle-Upper Jurassic applies to both types of ore body.

The stockwork copper ore bodies (Matahambre and La Esperanza) are hosted in hydrothermally altered gritstones and feldspathic sandstones. The copper mineral bodies therein have a N15°W strike and plunge at 50–60° to the northwest. The sandstones that host the copper mineralisation strike along N30-50°E, and dip 50–65° to the northwest. The stockwork ore bodies are thus totally discordant to the sedimentary bedding (see Fig. 6).

Matahambre deposit

The stockwork mineralisation in the Matahambre mine occurs mainly within four mineral bodies containing chalcopyrite, pyrite and quartz (Fig. 6). In the cross section shown in Fig. 6, the Cu ores appear to be stratiform, but this is due to the projection of the Cu bodies, along all the levels, onto the plane of the section.

Fabrics are either massive, brecciated or veined, and the mineralisation is hosted in the sandstones, not the black shales. The four mineral bodies are numbered 14, 19, 30 and 44 (Fig. 6). The number 14 body is developed

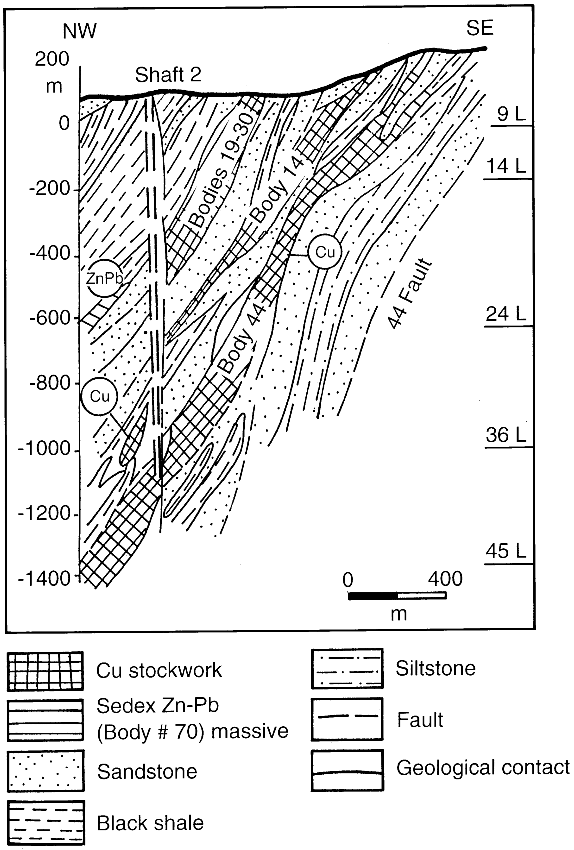

Fig. 6 Cross section through the Matahambre deposit (from data held by the Empresa Geologo-Minera Pinar del Rio, unpublished material from Fonseca personal communication 1990, De Los Santos et al. 1988, all as modified by Valdes-Nodarse et al. 1993)

between mining levels 5 and 35; surface outcrops occur as narrow, short gossans. This body has been mined out. Body number 19 stretches from a few metres above level 5 down to level 21 (625 m along strike); the ores occur as lodes separated from each other by about 15 m (Fonseca personal communication) 1990, and, as in number 14 body, the mineralised lodes are normal to the bedding. The number 30 body also occurs between the 5 and 21 mining levels, is analogous to the number 19 body and is mined out, access no longer being possible. The number 44 body is situated in the southeast of the middle part of the Matahambre deposit, from level 14 to level 45. Recent drilling indicates an extension of this body to the surface (Fig. 6) and it has a down-dip length of 1350 m. The 44 zone has been exploited since 1944.

SEDEX-type Pb-Zn ores, known as number 70 body, are located in the northwestern part of the Matahambre deposit (Fig. 6). This body is concordant with the bedding of the black shales of the Castellanos Member, San Cayetano Formation. The ore body has a long lode shape, 300 m long (NE), and extends from level 21 to level 32, with a thickness of about 10–25 m. The ores range from polymetalic-pyritic to pyrrhotitic, with massive structures and colomorphic fabrics. Pb + Zn grades are up to 6.0 wt.%. At the footwall, the number 70 Pb-Zn body changes to an uneconomic, discordant vein grid of mainly pyrite with little chalcopyrite, called the number 80 stringer zone.

Castellanos deposit

These ores occur within the upper, Castellanos Member of the San Cayetano Formation (Figs. 7 and 10). The Pb-Zn ore bodies are concordant with sedimentary bedding, comprising three lodes within black shales. Body number 1 is the largest and contains 98% of the estimated ore reserves. This body extends for 700 m along strike, and 300 m down dip; its thickness varies from 4.6 to 76 m. The main minerals found within these lodes are sphalerite, galena, pyrite, gold, plumbjarosite and barite. The fabrics are massive and brecciated. The proven tonnage at Castellanos has a cut-off of 2.5 wt.% Zn (as conventional Zn), with Cd = 0.017 wt.%. High tonnages of barite are also present.

The Cu stockwork ore body at the Castellanos deposit lies directly below the Pb-Zn bodies, and is discordant with respect to the enclosing sandstones and subordinate mudrocks. The stockwork ore body itself is formed by veins and lodes. Minerals found are pyrite,

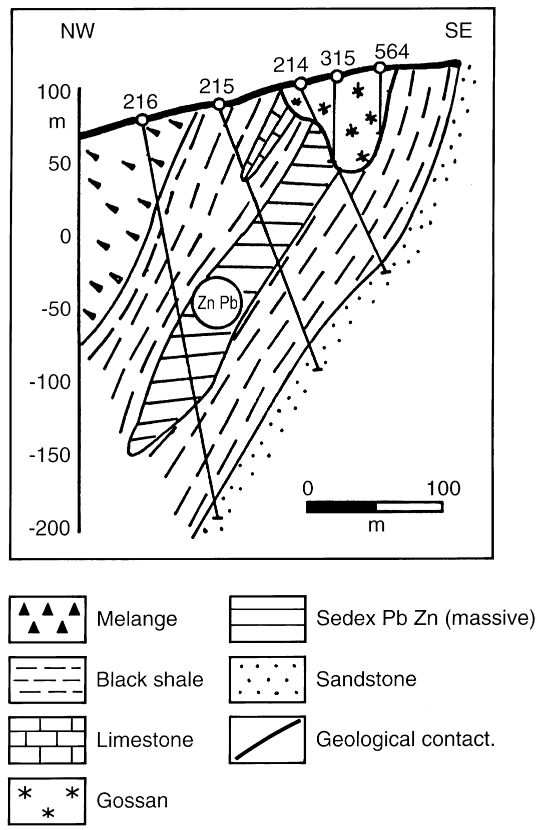

Fig. 7 Cross section through the Castellanos deposit (from data held by the Empresa Geologo-Minera Pinar del Rio, including unpublished data of Vologdin and co-workers 1977 personal communication, Barzana 1989 personal communication and Diaz A 1991 personal communication)

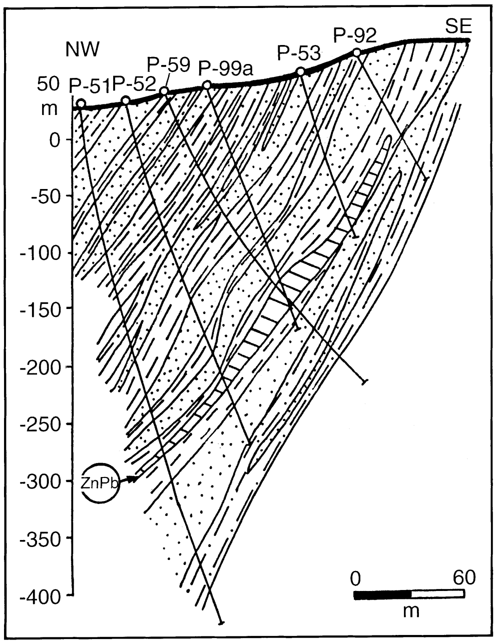

Fig. 8 Cross section through the Santa Lucia deposit (after De Los Santos et al. 1988; Robaina and Ovchinnikov 1989 personal communication). *Dots and dashes*, siltstone; *dots only*, sandstones, gritstones; *dashes only*, black shales; *horizontal lines*, Pb-Zn ore body

chalcopyrite and quartz, the last presumably representing the access channel fluid.

Santa Lucia deposit

The SEDEX-type Pb-Zn ores constitute over 20 bodies of lead and zinc-pyrite-sulphur-bearing minerals. Body number 1 (Fig. 8) contains 82% of the total estimated tonnage, has a length of 1 km, a width of 500 m and a thickness which varies from 2m to 53 m. The ore lies concordantly within the carbonaceous black shale host rocks (Fig. 8), and the ore itself is commonly framboidal and is thinly bedded. It is remarkable that geochemical haloes of lead-zinc are not present or are only found in the host rocks very close to the ore bodies themselves. Cu stockwork ores are absent. Pb + Zn grades are up to 7.0 wt.%; barite and silver contents are 14 wt.% and 52 g/mt, respectively.

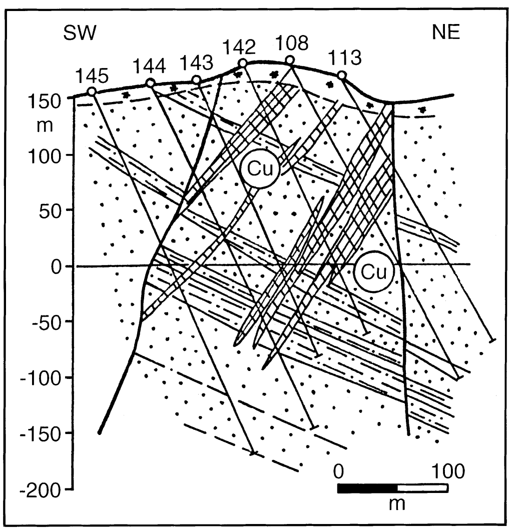

Fig. 9 Cross section through the La Esperanza deposit (after Diaz 1992 personal communication). This figure is drawn along the SW-NE strike of the host rocks and oblique to the Cu stockwork lenses, which plunge into the page, that is, to the NW. *Dots and dashes*, siltstone; *dots only*, sandstones; *cross-hatching*, Cu stockwork ore; *asterisks*, overburden

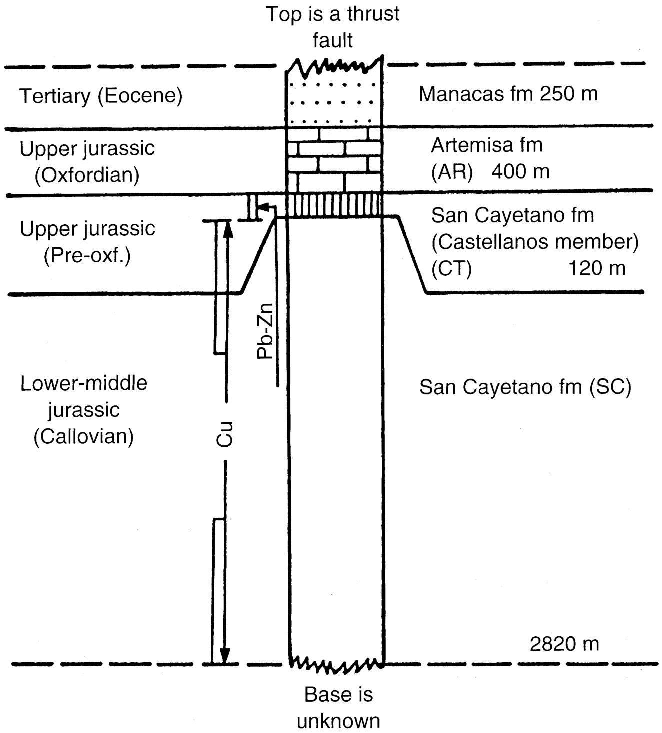

Fig. 10 Stratigraphic section through the Santa Lucia-Matahambre metallogenic district, Pinar del Rio Province, Cuba. The *symbols* used are the same as those in Fig. 2. *Cu*, position of Cu stockwork in the succession; *Pb-Zn*, position of polymetallic mineralisation in the succession; *AR*, Artemisa Formation, limestone; *CT*, Castellanos Member, black shales; *SC*, San Cayetano Formation, sandstones

La Esperanza deposit

Neither barite nor SEDEX-type Pb-Zn ores are found in this deposit. The Cu stockwork mineralisation, comprising eight ore bodies, is located within the lower part of the San Cayetano Formation, within fine-grained sandstones (Fig. 9). The ore bodies are vein-shaped and discordant across the strike of the host rock sandstones. This deposit has a strike length of 250 m, extends down dip for at least 250 m (known from exploration) and has a thickness of at least 5 m. Copper cross-cutting ores comprise only pyrite-chalcopyrite; fabrics are brecciated to massive. The average Cu grade is 1.63 wt.% (Table 1), with higher values occurring locally. The deposit has an unknown depth, dipping towards the NE (Fig. 9).

Table 1 Some worldwide examples of SEDEX deposits

District (D) or deposit	Country	Age of host rocks	Main elements	Host rocks	Average grades					Size (M tonnes)		Reference
					Pb %	Zn %	Cu %	$BaSO_4$ %	Ag g/t	Pb + Zn	Cu	
Silvermines (D)	IRL	C–D	Pb-Zn-Ba	Limestones	2.6	6.8		60	25	12.9		1
Gataga (D)	CAN	D	Pb-Zn-Ba	Black schist	2.2	7.8			48	30		2
Selwyn (D)	CAN	Cm–D	Zn-Pb-Ag	Clastic sed	5.5	7.8			70	63		2
Sullivan	CAN	PreCm	Zn-Pb-Ag	Turbidites	6.6	5.7			7	155		3
Howard Pass (XY)	CAN	S	Zn-Pb	Carbonaceous muds	2	5			9	525		4
Red Dog (Alaska)	USA	C	Zn-Pb-Ag	Black shale	17.1	5			82	77		5
McArthur River	AUS	PreCm	Zn-Pb-Ag	Dolostone	4	9.5		low	45	190		6
Matahambre	CUB	J	Cu	Sandstones			4				13 (E)	7
Body number 70	CUB	J	Zn-Pb	Black shale	1.97	4.2	0.21			2		7
La Esperanza	CUB	J	Cu	Sandstones			1.55				2.5	7
Castellanos	CUB	J	Zn-Pb-Cu	Sandstones	3.23	6.2	1.28	7.9	43	na		7
Santa Lucia	CUB	J	Zn-Pb-Ba	Black shale	1.83	5.7		14	52	na		7
Rammelsberg	GER	D	Zn-Pb-Cu	Black shale	10	19	2	high	120	22		6
Meggen	GER	D	Zn-Pb-Ag	Black shale	1.3	10	0.02	high	3	50		6

(E): Total production to date
na: non available
Key references 1: Macintyre 1982; 2: Carne and Cathro 1982; 3: MacClay 1991; 4: Goodfellow and Jonasson 1986; 5: Moore et al. 1986; 6: MacIntyre 1992; 7: this paper

Discussion

The majority of SEDEX deposits are formed at intracontinental rifts or in passive continental margin tectonic settings (Large 1980, 1983; Werner 1989, 1990; Goodfellow et al. 1991). SEDEX-type deposits are not reported from either magmatic arcs or from subduction zones. Within the northwest Cuban study area discussed here (Pinar del Rio), there is no evidence for a magmatic arc of Jurassic age (Valdes-Nodarse 1996, unpublished data).

Two metallogenic phases are identified in the Pinar del Rio metallogenic province: (1) irruptive, discordant and inferred vent-related Cu-S stockworks, associated with quartz (La Esperanza and Matahambre deposits); and (2) exhalative, concordant, syndepositional, stratiform Pb-Zn ores (Santa Lucia, Castellanos, and the number 70 body within the Matahambre deposit), most likely reflecting the influence of ancient brines (see Carne and Cathro 1982; MacIntyre 1982).

Tectonic setting of the ore deposits

Two tectonic events are inferred for the Santa Lucia-Matahambre metallogenic district. Evidence of the first event, of Upper Jurassic age, is masked by Eocene slumping and post-ore deposition events. This first tectonic event is exemplified by faulted synsedimentary systems with a NW-SE strike, and which show well-developed jointing and deformed fault planes within the Matahambre Mine stopes and in the Castellanos-La Esperanza adit levels. These tectonic elements are inferred to have been synchronous with ore formation, and were filled by warm fluids during irruptive mineralisation processes; these processes are considered to have formed the linear stockwork ore zones. These were subject to later thrusting and faulting, and now dip towards the NW.

The second tectonic event is more clearly evident, and is of Middle Eocene age (Laramic phase of the Alpine Orogeny). During this deformational event, the Represa, Manacas, Castellanos and Southeastern Castellanos tectonic units were formed, comprising a series of imbricate thrust slices. In plan view, these structural features are very complicated, analogous to the "array of rotated domino style" of MacClay (1991, p. 438), and characterised by transverse faults orientated along a NW-SE direction (Fig. 1), and which, in addition, displace a longitudinal fault system by some hundreds of metres.

Metallogenesis of the western Cuban ore deposits

A metallogenic district is based on a cluster of deposits, dominated by one or more basic metals (Gabelman 1976). In the present study, in addition, the tectonic

setting of the ore deposits is taken into account, as well as the metallogenic zonation first described by Simon (1987b), with some modifications and additions. In concert with the views of Large (1980, 1983), the ore deposits of the Santa Lucia-Matahambre metallogenic district were most likely formed within a third order basin, tens of square kilometres in size, which formed part of a first order basin of several thousand square kilometres. These size orders of basin preceded deformation and "telescopisation" (MacClay 1991).

Simon (1987b) subdivided the passive margin Antilles metallogenic province of Cuba into four metallogenic sub-provinces: Cuyaguateje, Sabalo-Sierra Morena, Loma del Viento and Santa Lucia – Matahambre. The deposits discussed here most likely had a sedimentary-exhalative (SEDEX) origin, thus being formed contemporaneously with the sedimentary host rocks, in the Lower – Upper Jurassic epoch (Zhidkov and Jalturin 1976).

The syngenetic ore deposit model proposed here contrasts with earlier epigenetic models formulated in the 1960s, which suggested that the ore was Eocene in age (Litavec 1970, unpublished report). The SEDEX model of Briskey (1986) provides the best analogue for the ore deposits of the Santa Lucia-Matahambre metallogenic sub-province. However, the economic cupriferous stockwork roots at Matahambre and La Esperanza contrast with this standard SEDEX model. In addition, the Cuban Cu deposits are exceptionally large compared to Briskey's (1986) general model (Table 1), and the Jurassic age of the Santa Lucia-Matahambre sub-province contrasts with the commonly mid-Proterozoic – Palaeozoic age of most of these deposits (Large 1980, 1983).

Numerical mineral deposit modelling for the Santa Lucia – Matahambre sub-province

The choice of the correct model for known ore deposits is of critical importance, when applied to prospecting within unexplored regions. For this reason, the western Cuban base metal deposits should be added to those ore bodies used to formulate the general SEDEX model of Briskey (1986).

MacCammon (1992) formulated a technique of numerical mineral deposit modelling, in which scores are calculated on the basis of the presence/absence of certain attributes of general deposit models, such as those given by Cox and Singer (1986). The attributes used are age range, rock types, alteration, mineralogy, geochemical signatures and associated deposit types. The maximum score for the SEDEX model of Briskey (1986) is 1970 points. For the deposits of the Santa Lucia-Matahambre sub-province, the scores obtained for this SEDEX model are:

Castellanos - - - - - 1860
Matahambre - - - - 1805
Santa Lucia - - - - 1755
La Esperanza - - - 1165

These relatively high scores support the general assertion made here, that Briskey's (1986) SEDEX model is suitable as an analogue for the western Cuban base metal deposits. The Castellanos deposit (Fig. 7) has the highest score, closest to the maximum possible for the SEDEX model. This Cuban deposit has a poorly developed stockwork zone, with a very well-developed polymetallic typically SEDEX-like upper ore zone. Matahambre has a huge stockwork copper zone (Fig. 6), an uncommon attribute for the general SEDEX model (Briskey 1986), thus giving a lower score of 1805 points.

These last two cases, Santa Lucia and La Esperanza, bear a less close resemblance to the Briskey (1986) SEDEX model. Santa Lucia is characterised only by Pb-Zn ores (Fig. 8), without any cross-cutting copper zone, whereas La Esperanza has only Cu stockwork ore bodies and no stratiform Pb-Zn mineralisation (Fig. 9). The exceptionally high Cu values at La Esperanza and Matahambre, in contrast to the general SEDEX model, are compatible with their lower points scores in the numerical modelling comparison. For the four major deposits within the Santa Lucia-Matahambre metallogenic sub-province, the mean score is 1646 points, thus representing an 83.5% match to Briskey's (1986) SEDEX model.

Conclusions

A sedimentary-hydrothermal genesis (Goodfellow et al. 1991) or a sedimentary-exhalative (SEDEX) genesis, within a passive margin tectonic setting (Simon 1987b; Valdes-Nodarse et al. 1993) is assumed for the western Cuban Pb-Zn-Cu deposits described here. The Matahambre deposits can be compared to the Tom deposit in Canada (MacClay 1991), with the difference that conglomerate and barite horizons are absent in the Cuban example. The Castellanos deposit of western Cuba has a geometry similar to that of the Tom deposit (MacClay 1991). The Santa Lucia deposit is comparable to the Driftpile deposit in Canada (MacClay 1991) and with the Hammaslahti base metal deposit in Finland, which is also hosted in black shales (Loukola-Ruskeeniemi 1991). The La Esperanza Cu stockwork mineralisation may be described as an extreme case of the classic SEDEX-type model.

The four large deposits comprising the Santa Lucia-Matahambre metallogenic district, as for other such districts worldwide, exhibit strong similarities to each other, but with differences as well, the latter reflecting particular features specific to each deposit. The base metal deposits of the Pinar del Rio metallogenic province of western Cuba belong to a passive margin tectonic setting and compare favourably to generally accepted SEDEX models such as that of Briskey (1986). Numerical modelling supports this assertion, as do comparisons with the grade/tonnage curves presented by Briskey (1986). If the deposits in this study are included in these curves, the curves show no significant differences

(Singer 1993 written communication). Stratiform mineralisation and cross-cutting stockworks in western Cuba have an Upper and Lower Jurassic age, respectively, and are thus older than the Upper Eocene age commonly associated with such mineralisation, as already pointed out by Laverov et al. (1967).

In the case of the Castellanos and La Esperanza deposits, the stockwork zones have yet to be explored properly, and economic depths are unknown. At Matahambre, copper ore is presently being exploited at a depth of 1535 m (level 45), and the deeper number 44 body mineralisation discussed previously shows no signs of being exhausted at present. Drilling has thus far located this copper zone down to level 46.

The depositional setting inferred for the host rocks to the mineralisation, namely the sandstones of the San Cayetano Formation, comprises continental fan-fluvial and deltaic palaeoenvironments. Inferred source terrains (Fig. 5) point to recycled orogenic rocks, thus suggesting Grenville or Pan-African terrains, located north and southwest of the present position of Cuba, within the Caribbean realm. It is reasonable to relate the inferred fluvio-deltaic origin of the host sedimentary rocks to an ancient south-southeast flowing large river system (Zhidkov and Jalturin 1976), with an associated Mississippi-type delta system (Simon 1987b), which deposited sediment along the passive margin of this part of Cuba.

Genesis of the western Cuban base metal deposits is thought to have been analogous to the model of Goodfellow and Jonasson, 1986; Goodfellow et al. 1991 for the Yukon-Selwyn Basin in Canada (Fig. 4).

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