Gold and copper metallogeny of Central America

Carl E. Nelson
Consultant, 2360 23rd Street, Boulder, CO 80304

ABSTRACT

Gold and copper deposits in Central America are hosted by island arc volcanic rocks of Late Cretaceous and younger age. Low potassium tholeiitic basalts form the base of the volcanic pile and were deposited in an intraoceanic island arc. Volcanism became more potassic with time and, by Late Miocene time, calc-alkaline andesites dominate the volcanic rock record. Alkaline volcanic rocks appeared about five million years ago but are underreported in older portions of the arc.

Porphyry copper deposits are centered on calc-alkaline plutons of intermediate (quartz diorite to quartz monzonite) composition and are typically anomalous in gold. Although some of the porphyry deposits contain in excess of a billion tonnes, none are in production. Bonanza gold veins cluster around sub-volcanic intrusions in districts which mimic the spacing of active volcanoes. Precious metal bonanzas, a number of which produced in excess of a million ounces of gold, are responsible for the bulk of historic gold production in Central America. Hot spring gold deposits are being discovered along a regional unconformity which marks the emergence of the present-day island arc from the ocean. Although discovered only recently, some of these deposits already exceed a million ounces. Host rocks include exogenous domes and surrounding pyroclastic aprons.

Exploration efforts today focus on bulk-mineable deposits: porphyry-related stockworks, skarns, and epithermal stockworks and disseminated deposits. Regional strike-slip faults parallel to the Nicaraguan depression control the distribution of both gold and copper throughout Central America. Age dates provide documentation for mineralization throughout the history of the arc, a period of close to 100 million years.

INTRODUCTION

Central America continues to lag behind the rest of the American cordillera in terms of mineral production. This state of affairs is the result of limited investment rather than limited mineral endowment. For the past half century Central America has been characterized by high political risk, ponderous bureaucracy, and mining codes designed to preserve sovereign control of mineral wealth. Yearly gold production never exceeded 200,000 ounces and, although regional exploration programs resulted in several new porphyry copper discoveries, none were put into production.

Recent improvements in both the political and the economic climate of Central America are attracting the attention of the international business community. Gross domestic product throughout the region, except for Nicaragua, has been growing at an annual rate of four to eight percent during the 1990s. Foreigners can now own 100 percent of a local business in most countries and repatriation of profits is gradually becoming easier. New mining laws (e.g. Honduras in 1970, Costa Rica in 1982, Panama in 1989, and Guatemala in 1985 and 1993) are being rewritten to attract foreign investment. State-owned mining companies are being disbanded.

As a result, exploration expenditures are up; new discoveries are being made; and, new mines are going into production. In Panama, the Remance gold mine has been in production since 1989 and the Santa Rosa deposit began producing gold in 1995. Cerro Quema announced a gold reserve in 1994 and feasibility studies are again underway at both the Cerro Colorado and the Petaquilla porphyry copper deposits. In Costa Rica, the Bellavista gold deposit has a reserve of close to a million ounces and the Crucitas gold deposit is over two million ounces. Active projects farther north include the El Dorado gold deposit in El Salvador, and, in Honduras, the Minas de Oro copper-gold skarn deposit and the San Andres gold mine. Several gold mines in Nicaragua (Limon, Bonanza, Libertad, and Siuna) continue to produce on the order of 30,000 to 40,000 ounces per year (down from 100,000 to 120,000 ounces per year in the early 1970s). In terms of past production, the relatively unexplored country of Nicaragua is the most generously endowed with mineral wealth in Central America.

This paper describes the lode gold and copper deposit types found in Central America with an emphasis on recent discoveries. The paper does not discuss seafloor manganese; lateritic nickel and aluminum; pegmatite-hosted tin, tungsten, and molybdenum; or, placer gold. Comprehensive lists of past-producing mines, including descriptions of many prospects, are provided in Roberts and Irving (1957), Levy (1970), and Kesler et al. (1990). Tables which accompany this paper assemble available size and grade data for the known deposits. Production figures for some deposits are incomplete and reserves are based on figures published by the property owners. In spite of these shortcomings, the tables can be used to identify the types of deposits which are likely to be found and to make some judgment of their potential size and grade. The

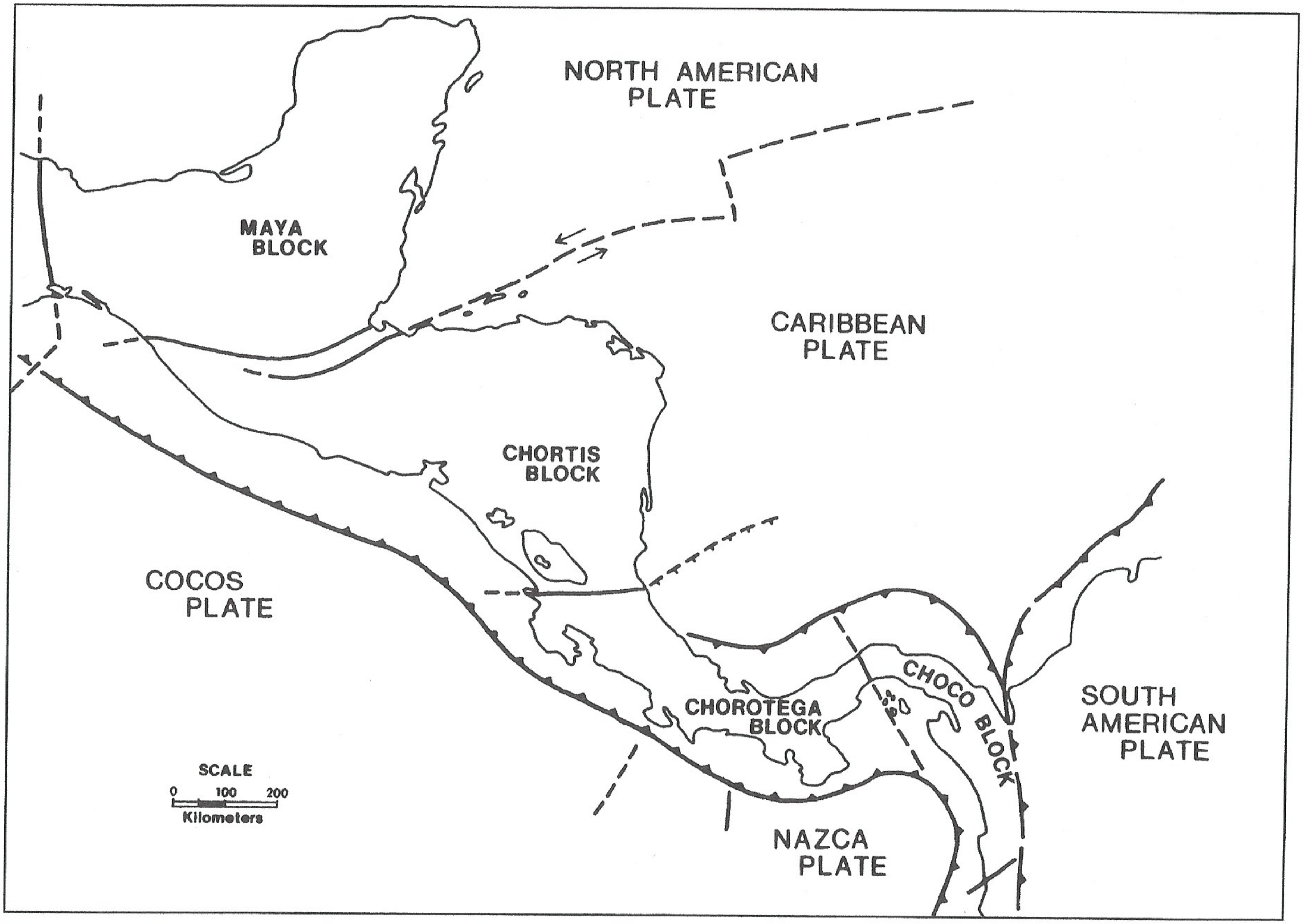

Figure 1—Regional tectonic map of Central America. Modified from Donnelly et al. (1990) and Escalante (1990).

Table 1—Copper and gold deposits hosted by metamorphic rocks.

Deposit (Map Location)	Past Production (Reserve/Resource)	References
Dipilto batholith Honduras Nicaragua (1)	unknown: numerous small gold mines including Alhambra,Azabache Conchagua, Murra, San Albino, San Juan Telapaneca, and La Virgen.	Levy, 1970 Kesler et al, 1990
Vueltas del Rio, Honduras (2)	466 kg (15,000 ounces) Au (10 million tonnes at 1.5 ppm Au) (4.1 million tonnes at 0.67 pct Cu)	Moe, 1992

deposit location maps can be used to focus on mineral districts, versus isolated occurrences and the geologic maps can be used to steer exploration towards more productive portions of the volcanic stratigraphy. Other summaries of metallogenesis in Central America include Kesler (1978), Ferencic (1971), and Nelson (1990, 1995).

REGIONAL GEOLOGY

Central America is divided into four crustal blocks (Fig. 1). To the north, the Maya and Chortís blocks are composed of Paleozoic igneous and metamorphic rocks, shelf carbonates and redbeds, and intermediate to silicic volcanic rocks. Case et al. (1990) classify this as continental and transitional crust. Farther south, the Chorotega and Chocó blocks are composed of mafic oceanic and accretionary crust overlain by basic to intermediate island arc volcanic rocks. Crustal thickness ranges from a high of 45 km in the Chortís block to less than 20 km in the Chorotega block.

The oldest rocks in Central America are metasedimentary and metavolcanic rocks of Paleozoic and possibly Precambrian age. These amphibolite facies rocks are exposed in the Maya block, along the Motagua fault zone, and southwards through the Chortís block as far as northern Nicaragua. The next youngest rock package is an unmetamorphosed sedimentary sequence deposited in intracontinental basins as North and South America drifted apart. This sequence of redbed sandstones and platform carbonates covers large portions of Guatemala, Honduras and Nicaragua.

Volcanic rocks of Cretaceous through Quaternary age form the third and most important rock group in terms of mineral endowment. Volcanic rocks can be divided into four sub-groups including: mafic and ultramafic oceanic crust, intraoceanic island arc basalts, calc-alkaline andesites and rhyolitic ignimbrites, and rift-related alkaline rocks. Brief descriptions of each rock group are provided below along with tables of associated mineral deposits.

Figures 2, 3, 4, and 5 show the areal distribution of these rock groups, regional structure, and the location of copper and gold deposits in Nuclear and Southern Central America. Available information on deposit size and grade is compiled in tables which are keyed to the maps and include references to the literature. Table 1 lists deposits hosted by metamorphic rocks; Table 2 covers skarn and replacement deposits; Table 3 provides data for porphyry deposits; Table 4, 5, and 6 compile information for bonanza, hot spring, and high-sulfidation deposits. All drill-tested porphyry copper deposits are included. Gold deposits are listed if production or reserves exceed 3000 kg (100,000 ounces).

Paleozoic Metamorphic Complex

The oldest dated rocks in Central America are amphibolite facies metamorphic rocks of Ordovician through Permian age. This complex is best exposed in central and eastern Guatemala where it is known as the Chuacús Series and in east-central Honduras where it is assigned to the Las Ovejas Group. Horne et al. (1976) provide age dates for plutons intruding this complex that range to as high as 305 million years. Overlying the Chuacús and Las Ovejas Groups are weakly metamorphosed rocks informally referred to as the Santa Rosa Group in Guatemala and the Cacaguapa Schist in Honduras and Northern Nicaragua. A detailed review of the Paleozoic metamorphic complex is provided in Donnelly et al. (1990).

Few gold or copper deposits have been discovered in metamorphic rocks (Table 1). A number of small gold and tungsten mines surround the Late Cretaceous Dipilto batholith in Nicaragua and Honduras (Kesler et al., 1990). And, the Vueltas del Río copper-gold deposit in northern

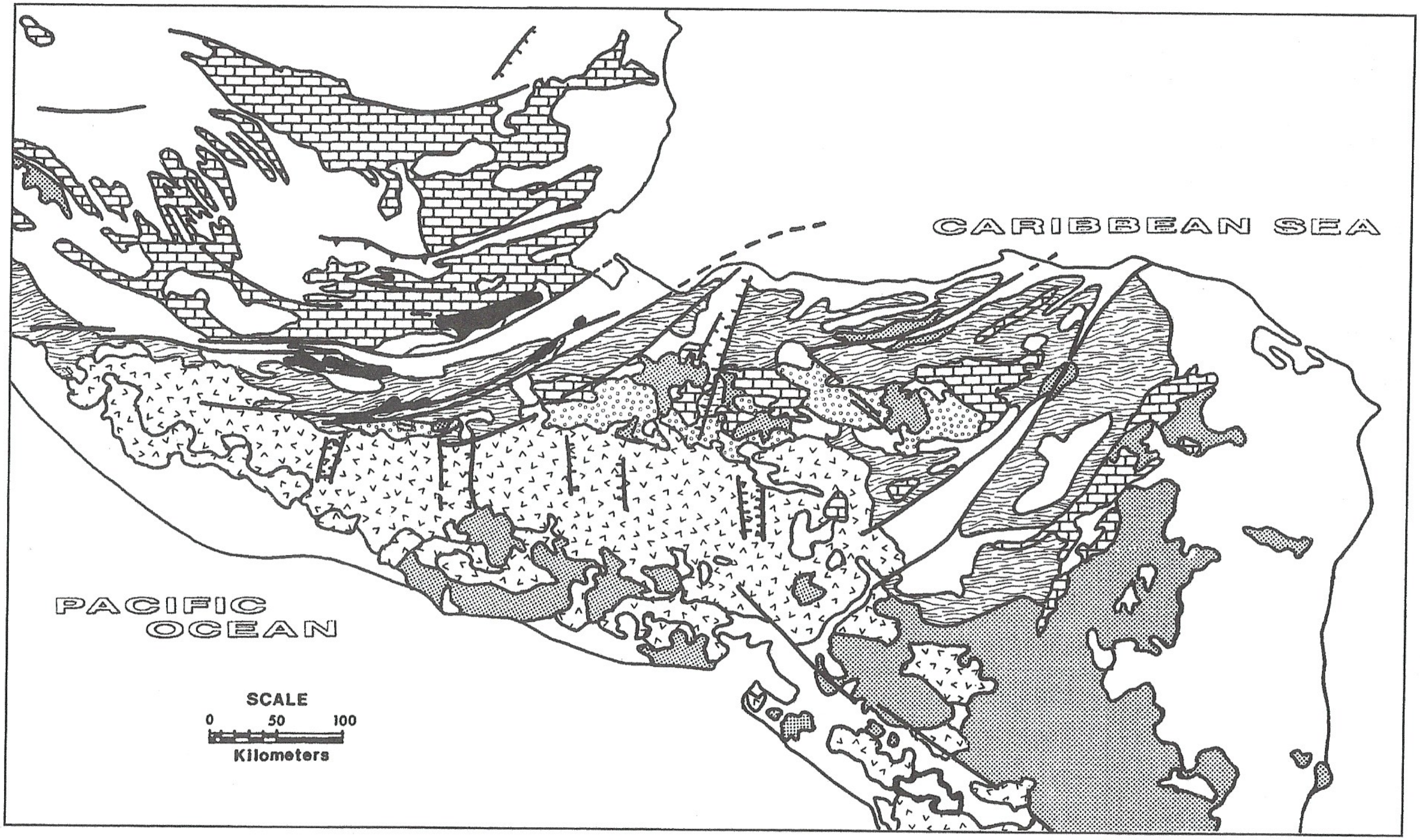

Figure 2—Geologic map of nuclear Central America. Modified from maps by Case and Holcombe (1980); Kozuch (1990); Bonis, et al. (1970); and Williams and Sanchez (1972). Areas underlain by metamorphic rocks are indicated with a curved line pattern; platform carbonates are shown as a brick pattern; redbeds are shown as open circles. Igneous rocks are divided into ultramafic (solid black), primitive island arc (stippled pattern), calc-alkaline ("v" pattern), and alkalic (horizontal dashed line) volcanic rocks.

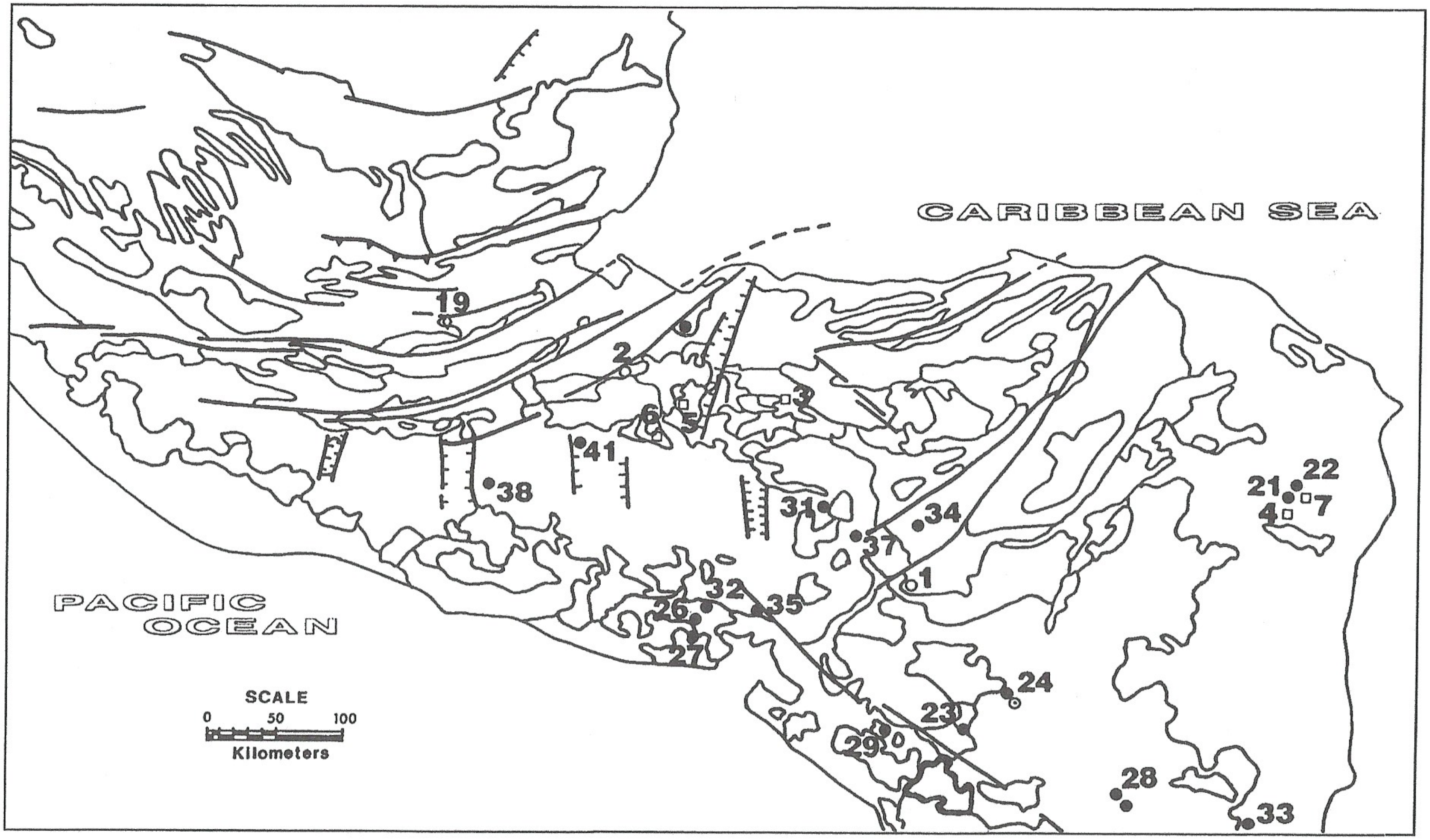

Figure 3—Gold and copper deposit location map for nuclear Central America. Numbers refer to deposits listed in Tables 1 through 6. Symbols correspond to the following deposit types: porphyry copper-gold deposits (circles with a solid dot), epithermal gold deposits (solid dots), massive sulfide deposits (diamonds), skarn and replacement deposits (squares), and shear-hosted gold and copper deposits (open circles).

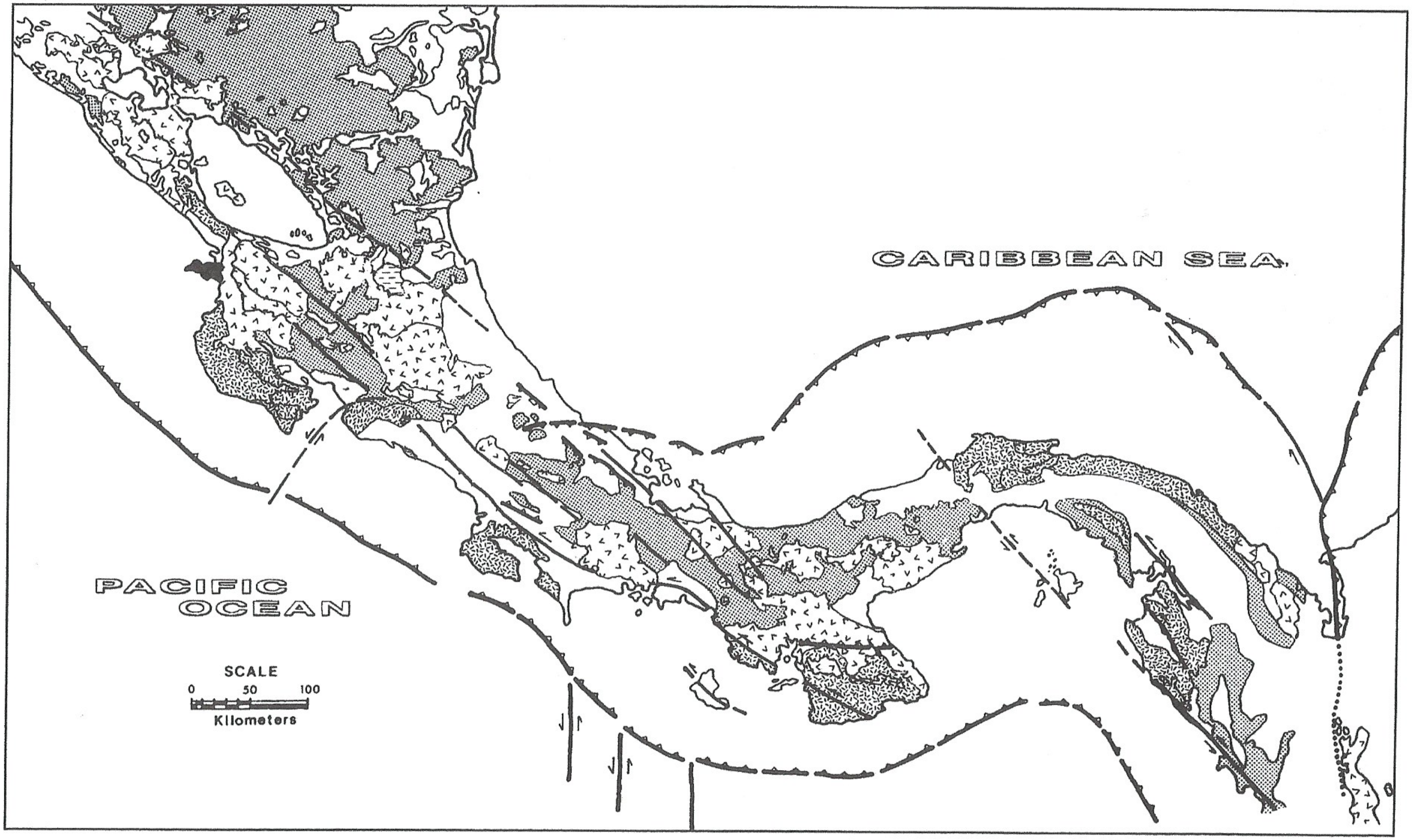

Figure 4–Geologic map of southern Central America. Modified from maps by Case and Holcombe (1980), Darce (1990), and Mann and Corrigan (1990). Igneous rocks are divided into ultramafic rocks (solid black); ocean floor (randomly oriented dash pattern); and, primitive island arc (stippled pattern), calc-alkaline island arc ("v" pattern), and alkaline (horizontal dashed line) volcanic rocks.

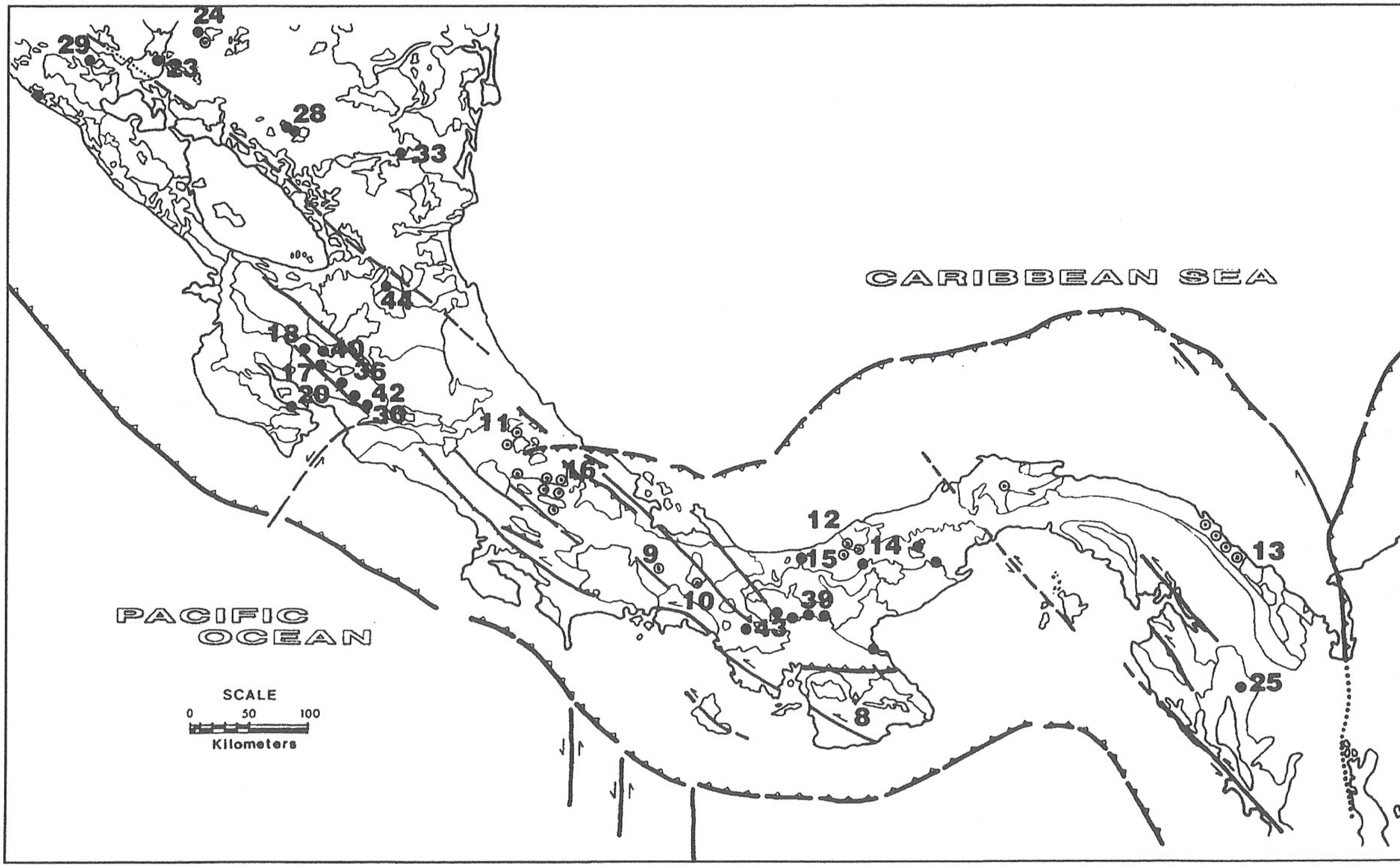

Figure 5–Gold and copper deposit location map for southern Central America. Numbers refer to deposits listed in Tables 1 through 6. Symbols correspond to the following deposit types: porphyry copper-gold deposits (circles with a solid dot), epithermal gold deposits (solid dots), high sulfidation gold and copper deposits (diamonds).

Table 2—Skarn and replacement deposits.

Deposit (Map Location)	Past Production (Reserve/Resource)	References
Minas de Oro, Honduras (3)	unknown past production, (27 million tonnes of 0.8 pct Cu, 1.4 ppm Au)	Fischer-Watt, 1992
La Luz (Siuna)*, Nicaragua (4)	45,000 kg (1.45 M ounces) Au from 12 million tonnes (1939-1962). (8.8 million tonnes of 2.6 ppm Au)	Plecash and Hopper, 1963 Darce and Tercero, 1992
Mochito*, Honduras (5)	750,000 tons Zn, 500,000 tons Pb 300,000 tons Cu, over 3 million kg (100 M ounces) Ag. (6 million tonnes of 8.5 pct Zn, 4.5 pct Pb, 0.5 pct Cu, 160 ppm Ag)	Johnson, 1993 United Nations Revolving Fund, 1988
Quita Gana, Honduras (6)	(1.521 million tonnes of 2.17 pct Cu, 2.46 pct Zn, 55 ppm Ag)	United Nations Revolving Fund, 1988
Rosita, Nicaragua (7)	5.35 million tonnes of 2.06 pct Cu 1 ppm Au, 16 ppm Ag (1958-1973). (127,000 tonnes of 8.2 ppm Au and 1.2 million tonnes of copper ore)	Plecash and Hopper, 1963 Darce and Tercero, 1992
Concepción Las Minas*, Guatemala (38)	(2.2 million tonnes of 0.75 pct Cu, 4.28 pct Zn, 0.58 pct Pb, 36 ppm Ag)	Machorro, Goodell and Vaides, 1996

* denotes mines that are currently in production

Honduras is hosted by a shear zone in Cretaceous metamorphic basement. Weathering at Vueltas del Rio has produced a surficial zone enriched in gold.

Mesozoic Platform Carbonates

Metamorphic basement is unconformably overlain by upper Jurassic to lower Cretaceous redbeds (Todos Santos Formation), lower to upper Cretaceous limestones (Yojoa Group), and upper Cretaceous to lower Tertiary redbeds (Valle de Angeles Group). Many of the ore deposits in this group are small lead-zinc and lead-zinc-silver replacements. However, the Mochito mine in Honduras has produced zinc, lead, copper, and silver and has been in production since 1948.

Copper and gold skarns are mined at the Rosita and La Luz (Siuna) mines in Nicaragua and are currently under evaluation at the Minas de Oro deposit in Honduras. Skarn and replacement deposits are listed in Table 2.

Cenozoic Volcanic Rocks

The oldest unmetamorphosed volcanic rocks in Central America are fragments of Jurassic and Cretaceous sea floor. These mafic and ultramafic rocks filled the opening Caribbean Basin and are preserved in the Motagua fault zone, as slices accreted to the west coast of southern Central America (Nicoya, Osa and Azuero Peninsulas), in eastern Panama (the Chocó block) and, possibly, in eastern Nicaragua (Venable, 1994). They host small, gold-bearing, massive sulfide deposits and small deposits of seafloor manganese.

Cenozoic metallogenesis in Central America really begins with the formation of an intraoceanic island arc off the west coast of the Americas during Late Cretaceous and Early Tertiary time. This volcanic rock sequence includes tholeiitic, calc-alkaline, and alkaline rocks. All three magma series have been recognized in Costa Rica (Kussmaul et al., 1991 and Alvarado, et al., 1992) where volcanism spans a period of roughly 80 million years (Campanian through to Present). Low potassium tholeittic basalts dominate the volcanic stratigraphy from Late Cretaceous through Miocene time (Alvarado, et al., 1992), a period of roughly 60 million years. Calc-alkaline basalts and andesites emerge during Late Miocene time, reflecting maturation of the island arc. According to Appel et al. (1994), the island arc in Costa Rica doesn't become truly calc-alkaline until the Piocene. Felsic ignimbrites throughout Central America are of Pliocene and younger age.

Alkaline volcanic rocks are found in north-south striking rifts related to the eastward progression of the Caribbean Plate and along northwest-striking strike-slip faults. The collision of Panama with South America began in Early to Middle Miocene time and resulted in the northward push of the Panama block along northwest-striking strike-slip faults (Pindell and Barrett, 1990). These faults facilitated the ascent of an underreported suite of alkaline volcanic rocks.

Most gold and copper mineralization in Costa Rica and throughout Central America is hosted by an older, dominantly tholeiitic island arc. One of the first deposits to form in this setting was Cerro Quema, a high sulfidation gold and copper deposit located on the Azuero Peninsula of Panamá. Similar, primitive, intraoceanic island arc volcanic rocks in the Dominican Republic host the Pueblo Viejo deposit (570 tonnes gold), the largest gold deposit in the Caribbean region.

In Central America, the early island arc is represented by units such as the Tilarán Group in Costa Rica, the Lower

Table 3—Porphyry copper and gold deposits.

Deposit (Map Location)	Past Production (Reserve/Resource)	References
Cerro Chorcha, Panamá (9)	6 drill holes in 1994 20 drill holes in 1995	Nelson, 1995 Arlo, 1995
Cerro Colorado, Panamá (10)	(1.3 billion tonnes, 0.76 pct. Cu, 0.01 pct Mo, 5.1 ppm Ag, and 0.08 ppm Au)	Clark, 1982 Nelson, 1995
Nari, Costa Rica (11)	(5 million tonnes of 0.3 pct Cu)	MacKevett, 1980 Nelson, 1995
Petaquilla and Botija, Panamá (12)	(744 million tonnes of 0.53 pct Cu, 0.014 pct MoS2, 1.3 ppm Ag, and 0.12 ppm Au)	Adrian Resources, 1994 Nelson, 1995
Rio Pito, Panamá (13)	(297,300 tonnes of 2.12 ppm Au and 4.04 ppm Ag)	United Nations Revolving Fund, 1981
Molejón, Panamá (14)	(6.8 million tonnes of 3.14 ppm Au and 4.49 ppm Ag)	Adrian Resources, 1994
Palmilla, Panamá (15)	(12.7 million tonnes of 0.3 pct Cu and 1.02 ppm Au)	Adrian Resources, 1994
Sukut, Costa Rica (16)	4 drill holes by Copper Range Expln.	Nelson, 1995

Table 4—Bonanza gold and silver deposits.		
Deposit (Map Location)	**Past Production (Reserve/Resource)**	**References**
Abangares, District, Costa Rica Tres Hermanos* San Martín El Recio (17)	29,000 kg (936,000 ounces) Au 18,700 kg (600,000 ounces) Ag (1900 - 1913) 3630 kg (116,000 ounces) Au from 363,000 tonnes ore (272,000 tonnes, 7.9 ppm) (290,000 tonnes, 7.9 ppm) (250,000 tonnes, 7.9 ppm) (658,000 tonnes, 1.7 ppm)	Chávez and Saenz, 1974 Huber et al., 1987
El Libano, Costa Rica (18)	3360 kg (108,000 ounces) Au from 109,000 tonnes ore. (117,000 tonnes at 26.13 ppm)	Huber et al., 1987
Bellavista, Costa Rica (20)	2706 kg (87,000 ounces) Au from 272,000 tonnes ore prior to 1960. (13,621,000 tonnes; 1.67 ppm Au), (37.4 M tonnes; 1.63 ppm Au)	Alan et al., 1992 Cooke, 1995
Bonanza*, Nicaragua (21)	87,100 kg (2.8 million ounces) Au 18,700 kg (600,000) ounces Ag 100,000 tons Zn, 18,000 tons Pb 5,000 tons Cu. (1.15 million tonnes at 5.73 ppm Au)	Stonehouse, 1976 Burn, 1969 Darce and Tercero, 1992
Vesubio, Nicaragua (22)	(1.58 million tonnes of 2.74 ppm Au, 15.1 ppm Ag, 0.84 pct Pb, 0.46 pct Cu, 5.08 pct Zn)	Darce and Tercero, 1992
La India, Nicaragua (23)	902 kg (29,000 ounces) Au and 1213 kg (39,000 ounces) Ag prior to 1954. (2.6 million tonnes of 8.6 ppm Au)	Darce and Tercero, 1992
La Reina, Nicaragua (24)	(544,000 tonnes at 6.51 ppm Au)	Darce and Tercero, 1992
Cana, Panama (25)	31,000 kg (1 million ounces) Au from 226,000 tonnes of ore (1665-1727), 31,000 kg (1 million ounces) Au from 900,000 tonnes ore (1887-1907).	Ruiz-Williams, 1992 Woakes, 1923
Divisadero, El Salvador (26)	2923 kg (93,971 ounces) Au and 176 kg (5,657 ounces) Ag (1905-1918)	Roberts and Irving, 1957
Hormiguero, El Salvador (27)	2260 kg (72,500 ounces) Au (1914-1918)	Roberts and Irving, 1957
La Libertad*, Nicaragua (28)	(3.78 million tonnes at 4.7 ppm Au)	Darce and Tercero, 1992

Table 4—Bonanza gold and silver deposits (continued).

Deposit (Map Location)	Past Production (Reserve/Resource)	References
Limón*, Nicaragua (29)	50,000 kg (1.6 million ounces) Au 124,000 kg (4 million ounces) Ag (1930-1987). (1.7 milion tonnes of 4.2 ppm Au)	Malone and Stoiber, 1987 Darce and Tercero, 1992
Mojón, Nicaragua (28)	(9.3 M tonnes; 2.12 ppm Au)	Snyder, 1995
Montes del Aguacate, Costa Rica (30)	15,000 kg (484,000 ounces) Au from 272,000 tonnes of ore prior to 1902 prior to 1902	Huber et al., 1987 Crespi, 1907 Chavez, 1974
San Juancito, Honduras (31)	23,200 kg (746,000 ounces) Au and 4 M kg (129,000,000 ounces) Ag from 6.35 million tonnes of ore (1882-1954)	Carpenter, 1954
San Sebastián, El Salvador (32)	23,300 kg (750,000 ounces) Au through 1945.	Roberts and Irving, 1957 Wuensch, 1917
Topacio, Nicaragua (33)	(507,000 tonnes at 6.51 ppm Au)	Darce and Tercero, 1992
Agua Fría, Honduras (34)	2504 kg (80,500 ounces) Au from 180,000 tonnes of ore (1935-1943)	Svanholm, 1976 Roberts and Irving, 1957
El Tránsito, Honduras (35)	(125,000 tonnes at 6.2 ppm Au and 185,000 tonnes at 8.5 ppm Au)	
La Unión, Costa Rica (36)	15,200 kg (490,000 ounces) Au	Cooke, 1974 (1909-1960)
Yuscarán, Honduras (37)	15,500 kg (500,000 ounces) Au and 886,600 kg (28.5 million ounces) Ag 1530-1821, 1880-1895, 1915-1923. (525,000 tonnes of 690 ppm Ag and 5.0 ppm Au)	United Nations Revolving Fund, 1988
San Pantaleón, Guatemala (38)	622,000 kg (20 million ounces) Ag	

* denotes mines that are currently in production

Table 5—Shallow Epithermal (Hot Spring) Gold Deposits

Deposit	Past Production/Reserve	References
Remance*, Panamá (39)	162 kg (5231 ozs) from 15,500 tonnes of ore (19th century), 840 kg (27,124 ozs) from 70,000 tonnes (1923-1932). (250,000 tonnes of 5.5 ppm Au)	Wleklinski, 1969
Río Chiquito, Costa Rica (40)	110 kg (3523 ounces) Au and 890 kg (28,600 ounces) Ag from 93,500 tonnes of ore (1987-1989). (1 million tonnes, 5.62 ppm Au)	Nelson, 1992
San Andres*, Honduras (41)	2177 kg (70,000 ounces) Au from 363,000 tonnes ore (1948-1954), 706 kg (22,712 ounces) Au from 485,371 tonnes (1983-1991). (8.6 million tonnes at 2.0 ppm Au)	Johnson et al., 1993
Santa Clara, Costa Rica (42)	1244 kg (40,000 ounces) Au (1981-1989). (4.5 million tonnes at 1.6 ppm Au)	Notholt, 1987
Santa Rosa*, Panamá (43)	(6.5 million tonnes, 1.7 ppm Au), (22.7 million tonnes, 1.4 ppm Au)	White, 1993; Johnson, Bikerman and Russell, 1995
Crucitas, Costa Rica (44)	(58 million tonnes; 1.2 ppm Au) Nov. 27, 1995	Northern Miner

* denotes mines that are currently in production

Table 6—Massive sulfide and high sulfidation deposits.

Deposit (Map Location)	Past Production (Reserve/Resource)	References
Cerro Quema, Panamá (8)	none (10 million tonnes of 1.26 ppm Au)	Torrey and Keenan, 1994; Nelson, 1995
Oxec, Guatemala (19)	1 million tonnes of 2.62 percent Cu	Petersen and Zantop, 1980

Coyul Group in Nicaragua, and the Matagalpa Formation in Honduras.

The distribution of volcanic rocks in Central America is shown on Figures 2, 3, 4, and 5 along with the distribution of older platform carbonates, redbeds and metamorphic basement. The maps divide the voluminous volcanic rock record of Central America into packages. Although the maps are preliminary, they show the distribution of ocean floor, a primitive intraoceanic island arc, the mature calc-alkaline island arc, and rift-related alkaline volcanic rocks throughout Central America. Improvements will come as additional chemical analyses and age dates are published, particularly for less well studied areas outside of Costa Rica. For instance, alkaline volcanic rocks are under-reported throughout Central America; some calc-alkaline rocks are present in areas shown as primitive island arc; and, areas mapped as Mesozoic seafloor also include some early, intraoceanic island arc volcanic rocks.

TECTONICS AND ORE DEPOSITS

Gold and copper deposits show a strong spatial association with the Nicaragua depression, an apical rift which developed over the subducting Nazca plate. This structure runs parallel to the Central American trench and measures sixty to eighty kilometers in width. Rift-related normal faults extend southeast as far as Colombia and northwest as far as Guatemala.

The orientation of mineralized structure within the northwest-striking rift provides evidence for strike-slip motion. East-west striking faults are mineralized at Santa Clara and Beta Vargas in Costa Rica and at Cerro Caballo in Panamá. North-south striking faults host gold mineralization throughout the Veraguas mineral belt and at Río Chiquito in Costa Rica. Left-lateral strike slip motion is particularly strong in southern Central America where the Panama block is pushing northward over the Caribbean Plate.

Strike-slip activity is not restricted to southern Central America. Evidence for left-lateral strike-slip along regional northwest-striking faults is found as far north as Honduras. Alteration at the La Victoria skarn prospect in Central Honduras exhibits several kilometers of left lateral displacement.

Extension facilitated the emplacement of shallow magmas. Throughout Central America, exogenous domes and plugs were intruded along rift-related structures. These dome fields are surrounded by pyroclastic aprons which host hot spring gold deposits including Crucitas, Santa Rosa, Remance, San Andrés, and Río Chiquito. Bonanza veins and stockworks are found in more deeply eroded terrane and cluster around centers of sub-volcanic intrusive activity. Porphyry deposits in southern Central America occur along the margins of composite batholiths of intermediate composition but also exhibit control by northwest striking structures (e.g. Petaquilla and Cerro Colorado).

Bonanza gold veins

Most past gold production in Central America has come from high-grade but low-tonnage, bonanza deposits. Bonanza deposits are discrete fissure veins and stockworks hosted by propylitically altered volcanic rocks (Nelson, 1990). The steeply-dipping, coarsely-crystalline veins are typically filled by a gangue of quartz, calcite and adularia and are mined for gold, silver and occasionally base metals. The Abangares district in Costa Rica has a recorded production of 936,000 ounces gold for the period 1900 to 1913. La Union and Montes de Aguacate, also in Costa Rica, probably each produced about a half million ounces. Other major bonanza gold producers include the El Limón and Bonanza mines in Nicaragua, the Cana district in Panama, San Sebastián in El Salvador, and Yuscarán in Honduras.

Maar-hosted gold stockworks

Propylitically altered early island arc andesites throughout Central America are intruded by plugs and flow-dome complexes of andesitic to rhyolitic composition. These shallow intrusive complexes cluster at a regional unconformity which separates lower, propylitically altered andesites from overlying, weakly altered volcanic rocks of the same composition. Regional quartz-chlorite-calcite alteration is probably the result of interaction with seawater. The unconformity marks the emergence of the island arc from the ocean.

Exogenous domes are surrounded by permeable blankets of pyroclastic ejecta and, in some districts, by a distinctive sequence of thinly bedded carbonaceous sediments and epiclastic breccias. Bulk mineable stockwork and disseminated gold deposits formed along the margin of maar craters and in carbonaceous, intravolcanic, sedimentary packages. Feeder veins are typically oriented north-south or east-west, sympathetic to strike-slip motion on regional northwest-striking faults. Recent discoveries exceed a million ounces and represent an important target for exploration. Upside potential, as indicated by the maar-hosted Pueblo Viejo deposit in the Dominican Republic, is an order of magnitude higher. Examples of maar-hosted gold deposits include the Santa Rosa and Remance deposits in Panama and the Crucitas deposit in Costa Rica. Santa Rosa is described by Nelson (1990), Tippett and Trever (1989), White (1993), and Johnson et al. (1995).

Porphyry copper-gold deposits

Porphyry-related copper and gold mineralization is associated with Paleocene to Pliocene age calc-alkaline intrusions. Most are emplaced into stratovolcanoes which were active prior to the closing of the Central American isthmus. In the western provinces of Panama, a high cordillera exposes plutons which range in age from 30 m.y. (Petaquilla) to 6 m.y. (Cerro Colorado). Intrusive activity is significantly older in eastern Panama and on the Azuero Peninsula where plutons and associated porphyry mineralization ranges in age from 65 m.y. (Cerro Azul) to 49 m.y. (Río Pito).

All of the porphyry systems studied to date in southern Central America are enriched in gold as well as copper. In some instances, the gold is zoned around the copper mineralization (e.g. Cerro Colorado). In other instances the gold is superimposed on or overlaps copper mineralization (e.g. Petaquilla, Río Pito, Cerro Chorcha). Veins and a breccia pipe in the Cana porphyry district of Panama produced over two million ounces of gold from high grade ore. Porphyry copper deposits of southern Central America are described by Kesler et al. (1977) and Nelson (1994).

Skarn and replacement deposits

Skarn-hosted copper, molybdenum and gold mineralization is hosted by Yojoa group limestones at Minas de Oro, Honduras. Johnson (1993) reports that the skarns surround a granodiorite pluton and are composed of diopside, magnetite and garnet. Skarn deposits in eastern Nicaragua are hosted by a carbonate-cemented clastic sedimentary sequence near the contact with Cretaceous diorite to granodiorite porphyry plutons (Venable, 1994). The Siuna (La Luz) deposit produced over a million ounces of gold (Plecash and Hopper, 1963).

El Mochito, the largest mine in Honduras, is a replacement deposit hosted by the Atima member of the Yojoa limestone. Since 1948, the mine has produced 11 million tons of ore containing 750,000 tons of zinc, 500,000 tons of lead, 300,000 tons of copper and over 100 million ounces of silver (Johnson, 1993). Ore occurs in chimneys and as a manto along the contact of limestone and the underlying Todos Santos Formation.

CONCLUSIONS

Most gold and copper deposits in Central America are hosted by island arc volcanic rocks which began to accumulate in Late Cretaceous time off the west coast of the Americas. Low-potassium tholeiitic basalts form the basal portion of the arc; calc-alkaline rocks dominate by the Middle Miocene Period. Alkaline volcanic rocks are typically Pliocene and younger in age but, are underreported from older portions of the volcanic stratigraphy.

Most historic gold production has come from epithermal bonanza veins and breccia pipes. Half a dozen bonanza vein districts in Central America have produced in excess of a million ounces of gold. Several recent bulk mineable gold discoveries also exceed a million ounces. The Santa Rosa deposit in Panama and the Crucitas deposit in Costa Rica each formed in a shallow epithermal environment. Host rocks include exogenous domes of basalt to rhyolite composition, tuff breccias which form a permeable pyroclastic apron, and thinly-bedded carbonaceous sediments and epiclastic breccias. Pueblo Viejo, located in the Domincan Republic, contains over 570 tonnes of gold (20 million ounces) and provides documentation for the upside potential of maar-hosted deposits.

Porphyry copper deposits in southern Central America are large and all have associated gold mineralization. Both Cerro Colorado and Petaquilla in Panama contain resources in excess of a billion tonnes. However, secondary enrichment is weak to absent; copper grade is typically less than one percent; and, gold adds only marginally to the value of the ore. Skarn and replacement deposits found in the Chortís and Maya blocks include iron, copper-gold, and lead-zinc-silver ore bodies. The Siuna skarn deposit in Nicaragua produced over a million ounces of gold and replacement orebodies at Mochito mine have produced copper, lead, zinc, and silver since 1948. Cerro Quema, the first high-sulfidation deposit to be discovered in Central America, is reported to contain ten million tonnes of 1.26 ppm gold.

New copper and gold discoveries can be expected along rift-related regional faults, particularly within an early, primitive, intraoceanic island arc. Areas recommended for exploration in southern Central America include the Costa Rican porphyry belt where it projects across the border into Panama, within exogenous dome fields along the margins of the Nicaraguan depression, and within largely unrecognized alkaline volcanic rock complexes in the Tertiary volcanic section. Areas recommended for exploration in nuclear Central America include the margins of north-south striking rift zones, the northern margin of the Caribbean Plate, and the margins of the Nicaraguan depression.

REFERENCES

Adrian Resources Ltd., 1994, Preliminary feasibility study completed - total property resources exceed 1.6 billion tonnes: Adrian Resources Ltd. press release, August 19, 1994.

Alan, M.A., Quesada, J.D., Seaward, M., and Hutton, D., 1992, Economic geology of the Bellavista gold deposit, Costa Rica: Society for Mining, Metallurgy, and Exploration, Inc., preprint number 92132, 7 p.

Alvarado, G.E., Kussmaul, S., Chiesa, S., Gillot, P.-Y., Appel, H., Worner, G., and Rundle, C., 1992, Resumen cronostrátigrafico de las rocas igneas de Costa Rica basado en dataciones radiométricas: Journal of South American Earth Science, v. 6, no. 3, p. 151-168.

Appel, H., Worner, G., Alvarado, G., Rundle, C., and Kussmaul, S., 1994, Age relations in igneous rocks from Costa Rica: Profil, v. 7, p. 63-69.

Arlo Resources, 1995, Summary of Panamanian Projects: unpublished report.

Bonis, S., Bohnenberger, H., and Dengo, G., 1970, Mapa geológico de la República de Guatemala (1:500,000): Instituto Geográfico Nacional, Guatemala.

Burn, R.G., 1969, The Pis Pis gold mining district of northeast Nicaragua: Mining Magazine, v. 120, p. 169-175.

Carpenter, R.H., 1954, Geology and ore deposits of the Rosario mining district and the San Juancito Mountains, Honduras: Geological Society of America Bulletin, v. 65, p. 23-38.

Case, J.E., and Holcombe, T.L., 1980, Geologic - Tectonic map of the Caribbean Region (1:2,500,000 scale): United States Geological Survey Miscellaneous Investigations Series Map.

Chavez, R., 1974, The Aguacate mines of Costa Rica - Geology and Appraisal: Informes tecnicos y nota geologicas no. 57, Dirección de Geología, Minas y Petróleo, 49 p.

Chavez, R., and Saenz, R., 1974, Geologia de la Cordillera de Tilarán: Ministerio de Economía, Industria y Comercio, Dirección de Geología, Minas y Petróleo, 49 p.

Clark, G.H., 1982, The Cerro Colorado Porphyry Copper Project: internal report for the RTZ Group Exploration Conference, Johannesburg, 40 p.

Cooke, B.J., 1995, Geological resources double to 2 million ounces gold at Bellavista Gold Project, Costa Rica: Canarc Resource Corp. News Release, October 3, 1995.

Cooke, H.R., 1974, La Union gold district, Montes de Oro, Puntarenas, Costa Rica: Cooke, Everett and Associates, Inc., unpublished report number 151 E, 28 p.

Crespi, R.A., 1907, Geology and development of Aguacate mines, Costa Rica: The Mining World, November 9, p. 847-848.

Darce, R.M., 1989, Mineralogical alteration patterns, chemical mobility and origin of the La Libertad gold deposit, Nicaragua: University of Stockholm, Department of Geology, PhD dissertation, 103 p.

Darce, M., 1990, Mineralogic alteration patterns in volcanic rocks of the La Libertad gold mining district and its surroundings, Nicaragua: Economic Geology, v. 85, p. 1059-1071.

Darce, R.M., and Tercero, G.A., 1992, Estado de reservas auriferas del sector minero Nicaraguense al 1 de Enero de 1992: Direccion General de Geología, INMINE Central.

Dengo, G., Levy, E., Bohnenberger, O., and Caballeros, R., 1969, Mapa metalogenético de América Central (1:2,000,000 scale): Instituto Centroamericano de Investigación y Technología Industrial (ICAITI).

Donnelly, T.W., Horne, G.S., Finch, R.C., and Lopez-Ramos, E., 1990, Northern Central America; the Maya and Chortís blocks, *in* Dengo, G., and Case, J.E., eds., The Caribbean Region: Boulder, Colorado, Geological Society of America, The Geology of North America, v. H, p. 37-76.

Escalante, G., 1990, The geology of southern Central America and western Columbia, *in* Dengo, G., and Case, J.E., eds., The Caribbean Region: Boulder, Colorado, Geological Society of America, The Geology of North America, v. H, p. 201-230.

Fischer-Watt, 1992, October 29 report to the shareholders: FischerWatt Gold Company, Inc., 2 p.

Ferencic, A., 1971, Metallogenic provinces and epochs in Southern Central America: Mineral. Deposita, v. 6, p. 77-88.

Harju, H.O., 1979, Exploration of Eximbal's nickel laterite deposits in Guatemala, in Evans, D.J.L., ed., International laterite symposium: Society of Mining Engineers, p. 57-84.

Horne, G.S., Clark, G.S., and Pushkar, P., 1976, Pre-Cretaceous rocks of northwestern Honduras: Basement terrane in Sierra de Omoa: Amer. Assn. of Petrol. Geol., v. 60, p. 566-583.

Huber, D.F., Page, N.J., Howe, S.S., and Solano, C., 1987, Mines, prospects and mineral occurrences in Costa Rica: United States Geological Survey Miscellaneous Investigations Series Map I-1865, p. 18-33.

Johnson, M.J., 1993, Mining and mineral deposits of Honduras and El Salvador, in Randol at Acapulco '93 - Conference Proceedings: Randol International Ltd., p. 87-100.

Johnson, M.D., Hillemeyer, F.L., Bybee, R.W., 1993, Geology and mineralization at the San Andres mine, Honduras: Society for Mining, Metallurgy, and Exploration, Inc., preprint number 93-206, 24 p.

Johnson, M.D., Bikerman, D., and Russell, M., 1995, Function of contemporary modelling in mine development at Mina Santa Rosa, Veraguas Province, Panama: Soc. of Mining Engineers, Preprint Series.

Kesler, S.E., 1978, Metallogenesis of the Caribbean region: Journal of the Geological Society of London, v. 135, p. 429-441.

Kesler, S.E., Sutter, J.F., Issigonis, M.J., Jones, L.M., and Walker, R.L., 1977, Evolution of porphyry copper mineralization in an oceanic island arc, Panama: Economic Geology, v. 72, p. 1142-1153.

Kesler, S.E., Levy, E., and Martin, F.C., 1990, Metallogenic evolution of the Caribbean region, *in* Dengo, G., and Case, J.E., eds., The Caribbean Region: Geological Society of America, The Geology of North America, v. H, p. 459-482.

Kozuch, M.J., 1990, Mapa geológico de Honduras (1:500,000): Instituto Geográfico Nacional, Honduras.

Kussmaul, S., Tournon, J., and Alvarado, G.E., 1991, Evolucion de las rocas plutónicas y volcánicas subalkalinas del Neógeno y Cuarternario de Costa Rica: Memorias Simposio sobre Magmatismo Andino y su marco Tectónico, Manizales, Colombia. v. 1, p. 23-44.

Levy, E., 1970, La metalogenésis in América Central: Publicaciones Geológicas del Instituto Centroamericano de Investigación y Tecnología Industrial, No. III, p. 17-57.

MacKevett, E.M., Jr., 1980, Geology and exploration of the Matama II (Nari) project area, Costa Rica, C.A.: internal Mapco report, 26 p.

Malone, G.B., Stoiber, R.E., 1987, Caldera-related gold mineralization of the El Limon mining district, western Nicaragua: Journal of Volcanology and Geothermal Research, v. 33, p. 217-222.

Mann, P., and Corrigan, J., 1990, Model for late Neogene deformation in Panama: Geology, v. 18, p. 558-562

Moe, K., 1992, Canadian firm steps up gold exploration in Honduras: Mining Record, v. 103, no. 17, p.1

Nelson, C.E., 1990, Bulk mineable epithermal precious metal deposits of the Circum-Caribbean region, *in* Hausen, D.M., Halbe, D.N., Petersen, E.U., and Tafuri, W.J., eds., Proceedings of the Gold '90 Symposium: Society for Mining, Metallurgy and Exploration, Inc., p. 149-161.

Nelson, C.E., 1992, Gold mineralization in maar craters - two examples from southern Central America in Randol at Minexpo '92 Proceedings: Randol International Ltd., p. 55-58.

Nelson, C.E., 1995, Porphyry copper deposits of southern Central America: Arizona Geological Society Digest, v. 20, p. 553-565.

Nelson, C.E., 1996, Gold and copper metallogeny of Central America, *in* Coyner, A.R. and Fahey, P.L., eds., Geology and Ore Deposits of the American Cordillera: Geol. Soc. Nevada Symposium, Reno/Sparks, Nevada, April, 1995.

Northern Miner, 1995, Placer Dome boosts budget to explore and develop international gold properties: Northern Miner, Nov. 27, 1995, p. C12

Notholt, A., 1987, Central America: Mining Annual Review, p. 326-328.

Petersen, E.U., and Zantop, H., 1980, The Oxec deposit, Guatemala; an ophiolite copper occurrence: Economic Geology, v. 59, p. 753-767.

Pindell, J.L., and Barrett, S.F., 1990, Geological evolution of the Caribbean region; a plate-tectonic perspective, *in* Dengo, G., and Case, J.E., eds., The Caribbean Region: Boulder, Colorado, Geological Society of America, The Geology of North America, v. H, p. 405-432.

Plecash, J., Hopper, R.V., 1963, Operations at La Luz Mines and Rosita Mines, Nicaragua, Central America: Canadian Mining and Metallurgical Bulletin, p. 624-641.

Roberts, R.J., and Irving, E.M., 1957, Mineral deposits of Central America: United States Geological Survey Bulletin 1034, 205 p.

Ruiz-Williams, H., 1992, Executive summary - Cana Mining District, Panamá: unpublished report, 6 p.

Snyder, H.R., 1995, Greenstone Resources Third Quarter Report: November 24, 1995.

Stonehouse, J.M., 1976, Movement of mineralizing fluids, Bonanza mining district, Nicaragua (M.Sc. thesis): Hanover, New Hampshire, Dartmouth College, 64 p.

Svanholm, J., 1976, Gold in Honduras - Where to find it: Publicaciones Geológicas del Instituto Centroamericano de Investigación y Technología Industrial (ICAITI), No. V, Guatemala, p. 206-236.

Tippett, M.C. and Trever, P.F., 1989, The isthmus of Panama - A forgotten El Dorado: Society of Mining Engineers, Preprint number 89-56, 4 p.

Torrey, C. and Keenan, J., 1994, The Cerro Quema Project, Panama: unpublished fieldtrip guidebook.

United Nations Revolving Fund for Natural Resources Evaluation, 1981, Exploracion para cobre y oro en Río Pito, Panamá: UNRFNRE final report to the government of the Republic of Panama: DP/PAN/NR/77-001, 150 p.

United Nations Revolving Fund for Natural Resources Evaluation, 1988, Exploration for precious and base metal in Honduras: Project HON/NR/83/001, 1987 Annual Report, 79 p.

Venable, M.E., 1994, A geologic, tectonic, and metallogenic evaluation of the Siuna Terrane: Univ. of Arizona, unpubl. PhD thesis, 154 p.

White, D.C., 1993, Geology and mineralization of the Santa Rosa gold deposits, Panama: Society of Mining Engineers, Preprint Series, 5 p.

Williams, R.L., and Sanchez, J.K., 1972, Mapa geológico de Nicaragua Occidental (1:250,000): Division de Geológia de Catastro, Nicaragua.

Wleklinski, S., 1969, Gold deposits of northern Veraguas: United Nations Development Program, Mineral Survey of the Azuero Area, v. 1, 113 p.

Woakes, E.R., 1923, The Darien gold mine, Panamá: Mining Magazine, p. 270-278.

Wuensch, C.F., 1917, Geology of the San Sebastián mine, Salvador: Mining Science Press, p. 345-350.

Recommended citation:
Nelson, C.E., 1996, Gold and copper metallogeny of Central America, *in* Coyner, A.R., and Fahey, P.L., eds., Geology and Ore Deposits of the American Cordillera: Geological Society of Nevada Symposium Proceedings, Reno/Sparks, Nevada, April 1995, p. 1397-1411.