PURPOSE AND SCOPE

This report summarizes observations acquired during my site visit to the Juarez-San Francisco mine and vicinity, located approximately 6 km west of Tajitos, Sonora, Mexico. I explored various prospect pits, old mines, and arroyos with geologist Dr. J.J. Irwin and my field assistant, Miguel Espinoza on January 15-16, 2005. I document below my impressions drawn from observations of outcrops on the property and my knowledge of geology and structure of northern Sonora. Although these preliminary conclusions require confirmation by more detailed geological mapping and drilling studies, I believe the property has excellent potential for development as a Picacho-type gold mine.

GENERAL STRATIGRAPHY AND MAGMATIC CHRONOLOGY

The property is situated entirely within the northwest-trending Jurassic magmatic arc of Sonora. Although none of the units at the site have been radiometrically dated, the rock types and stratigraphic sequence bear strong similarities to sections I have mapped in Sierra de La Madera near Imuris, Sonora (Nourse, 1995) and in Sierra El Batamote and Sierra El Alamo north of Caborca (Nourse, 2001). The closest correlative rocks, mapped by Corona (1979), occur in the vicinity of the Cerro Basura microwave tower ~25 km northwest of Caborca. U-Pb zircon geochronology of igneous components of the Jurassic arc in north-central Sonora and southern Arizona is detailed in articles by Anderson et al. and Haxel et al., respectively, soon to be published as part of a Geological Society of America Special Paper on geology of Sonora. The digital geologic map presented in Figure 1 is a compilation of published geological mapping in the Caborca region. Map units in the Tajitos-Noche Buena area are largely based on interpretation of Landsat images.

Most of the classic Jurassic magmatic arc lithologies characteristic of the southwestern United States are present in the vicinity of the Juarez and San Francisco mines. These include massive hypabyssal rhyolite or rhyodacite porphyry, flow-banded rhyolite interstratified with quartz arenite, propylitized andesite or dacite porphyry, green or brown lithic sandstone associated with granule-pebble conglomerate, and phyllitic or sericitic siltstones and mudstones. All of these units are known to have formed between 175 Ma and 160 Ma elsewhere in Sonora and Arizona (Anderson et al., in press; Haxel et al., in press). Narrow, localized zones of cleavage or foliation, developed under lowermost greenschist facies conditions, locally overprint
some of these rocks. Brittle fractured zones within the rhyolites and low-angle fault zones separating footwall rhyolites from Jurassic sediments in the hanging walls appear to be especially important hosts for the gold mineralization elsewhere and here.

A distinctive nonfoliated fine-grained hornblende monzodiorite intrusion occurs southeast of the San Francisco mine. This rock appears to post-date the foliation event and is possibly correlative with a separate Late Jurassic (~150 Ma) phase of alkaline magmatism recognized by both Anderson et al and Haxel et al. (in press). The Late Jurassic(?) monzodiorite provided a potential heat source for driving hydrothermal fluid activity and initial gold mineralization in quartz veins. However, three younger magmatic episodes are also known in the Caborca region. These include emplacement of Late Cretaceous granodiorite and dacite (Jacques-Ayala et al, 1990; Oskin and Nourse, unpublished $^{40}\text{Ar}/^{39}\text{Ar}$ dating), extrusion of hornblende andesite and basaltic andesite at 24 Ma (Oskin and Nourse, unpublished $^{40}\text{Ar}/^{39}\text{Ar}$ dating), with likely associated mafic-intermediate dike swarms (Nourse, 2001), and Mid Miocene (~15 Ma) intrusion of biotite granodiorite at Cerro Carnero (Jacques-Ayala et al., 1990). One or more of these igneous events may have remobilized fluids during Cretaceous and/or Tertiary time, potentially concentrating ore bodies on the structures described below.

**STRUCTURE AND ITS RELATIONSHIP TO MINERALIZED BODIES**

In walking the site with Dr. J.J. Irwin, I was impressed by the wide distribution and recurrence of brittle deformation, expressed both as steeply to moderately dipping fault contacts and as pervasively shattered zones with hundreds of meters of horizontal aerial extent. At first glance the structure appears to be chaotic as a consequence of multiple episodes of faulting and fracturing, but when one considers the tectonic history of the region and looks for specific conjugate fault orientations and fault characteristics in context of crosscutting relationships, a systematic pattern emerges. Based on previous studies of the structural geology of northern Sonora (Corona, 1979; De Jong, 1988; Nourse, 1990, 1995, 2001; Oskin and Stock 2003; Nourse et al, in press; Anderson et al., in press), the various orientations and styles of faulting can be grouped into specific age categories. However, much more mapping is necessary to determine the origin and sequence of different generations of structures and to verify the absolute structural chronology. The main complications arise from the fact that there are two episodes (Late Jurassic and Late Cenozoic) of strike slip faulting along northwest trends known in the region in
addition to two episodes of northeast-southwest directed low angle faulting (Laramide thrusting and Miocene extensional detachment). The relative importance of these four structural imprints and their association with mineralization has yet to be worked out. It is likely that earlier generations of faults have been reactivated, possibly more than once or repeatedly.

As sketched in Figure 2, western Sonora has twice been profoundly affected by strike-slip faulting along northwest-trends. Late Jurassic movement of the left-lateral Mojave-Sonora megashear (located on Figure 1; see also Anderson and Silver, in press) created a dominant set of steeply-dipping N70±10°W striking faults within the region of the Middle Jurassic magmatic arc. Secondary right-lateral faults with N50±10°E strikes were also produced as the conjugates in this system (Anderson and Nourse, in press). Much later, movement of the proto-San Andreas fault system between 12 Ma and 6 Ma caused a system of N35±10°W striking right-lateral faults with conjugate N25±10°E striking left-lateral faults to overprint the region 100+ km northeast of the present-day Gulf of California (Gans, 1997; Oskin and Stock, 2003). My initial impression is that San Andreas-type faults have had relatively minor effects on the property, based on the observation that few steep faults with N35°W strikes are recognized.

Late Jurassic strike-slip faults do appear to be important in terms of creating conduits deep into the crust and causing initial focus of the gold mineralization. We visited numerous sites in which an early-generation of mineralized quartz veins are developed along steep fault zones with predominately N70°W strikes. Several of these fault zones display subhorizontal striations that record strike-slip fault displacements. The quartz veins appear to have been injected into the faults, and later brecciated. Given the likelihood that these faults are part of a major plate-boundary transform fault (the Mojave-Sonora megashear) that penetrated the entire crust, perhaps the original source of gold should be classified as “orogenic” implying derivation from the upper mantle.

A later episode of low-angle faulting is strongly manifested. These less coherent structures are associated with penetrative breccia zones, some parts of which are mineralized. Many of the faults we visited have shallow to moderate dips with striations indicating dip-slip or oblique-slip displacements. Similar faults are described in Jurassic strata at Sierra La Gloria, ~15 km to the east (Corona, 1979; see also thrust barbs mapped on Figure 1). A duplex structure, in which a tabular mass of Jurassic sandstone is repeated or duplicated between two thrusts that bifurcate and then rejoin, was observed in the arroyo at approximately 364000E,
3427000N). This duplex is quite impressive in the context of its potential for repeating ore bodies along low-angle faults. It must project into the subsurface to the southwest for some distance. Duplex structures are characteristic of Laramide age deformation elsewhere in Sonora. Several examples occur in the vicinity of La Choya Mine (Iriondo et al., in press). My preliminary geometric impression is that several of the late low-angle structures have recorded NE or SW directed thrusting. Thrusting of similar orientation within the Sonora gold belt is known to have occurred during Laramide time; e.g., between 71 Ma and 55 Ma at Sierra El Chanate and Sierra El Batamote (Nourse, 2001) and between 75 Ma and 39 Ma near La Choya Mine (Iriondo et al., in press). I suspect that one important control on the mineralizing fluids in the Juarez-San Francisco Mine district has been movement along Laramide thrusts during one or more of the Tertiary magmatic episodes described above. An important objective of future mapping should be to identify places where low angle mineralized thrusts intersect, and possibly displace, the high-angle, high-grade ore bodies.

The entire property appears to reside in the footwall of a major Miocene detachment fault (low-angle normal fault). Figure 1 locates this fault with hachures where I have mapped it along the southern flank of Sierra El Alamo and Cerro Basura. The detachment fault separates a footwall of greenschist facies Jurassic rocks from a hanging wall of unmetamorphosed Upper Cretaceous and Tertiary red beds (nonmarine conglomerate and sandstone). Miocene normal faulting in the Caborca region appears to have been driven by NE-SW or E-W extension. The importance of Miocene extension in the property is presently unknown although I observed several late-stage quartz veins with northerly strikes that appear to fill tension fractures. Distinguishing Miocene extensional structures from the Laramide thrusts will require additional work.

**CONCLUSIONS AND RECOMMENDATIONS**

The Juarez-San Francisco property exhibits all the geologic characteristics of an ore body of Picacho type (Drobeck et al., 1986; Ruiz, 1986). The term “Picacho Peak type gold” was coined by Ruiz (1986) to describe structurally controlled lode gold with associated disseminated gold. At the Picacho Mine of southeastern California, a low-angle normal fault (Chocolate Mountains detachment) has created extensive breccia zones with bounding low-permeability rocks. Four ore bodies are localized within these breccia zones and along steeper footwall faults.
that are truncated by the detachment fault (Drobeck et al., 1986). Picacho type gold deposits are more generally extrapolated to the Sonoran gold belt, where low-angle breccia zones that host the ore bodies may owe their origin to Laramide thrusting, Miocene detachment faulting, or both. These low angle faults, where discovered at shallow depths, have proven to offer excellent targets for open pit mining.

The structures at Juarez-San Francisco are on strike with and of similar geometry to the fault-controlled ore bodies at Noche Buena, La Choya, Herradura, and Lluvia de Oro (see Summers et al., 1998; Thomas, 1998; Garza et al., 1998; Teran Cruz, 1998; Iriondo, 2000; Iriondo et al., in press). Although Precambrian basement is involved in two of these mines (Herradura and La Choya), my personal field experience and perusal of articles in the Clark volume on northern Sonora gold deposits (1998) indicates that the ore bodies are independent of host rock age. Instead, common denominators of the gold deposits appear to include the following: (1) presence of a shallow-dipping to subhorizontal, pervasively fractured zones developed within quartzo-feldspathic host rocks, (2) positioning of the fractured low-grade mineralized zones above narrow, steeper, high-grade ore bodies, (3) impermeable “cap rocks,” e.g., unfractured granite or rhyolite or phyllosilicate-rich sediments, phyllite, or schist situated above the low-angle ore bodies and configured such that upward fluid migration is impeded, and (4) nearby magma bodies to drive fluid flux and mineralization of the brecciated zones. The initial source of the gold remains speculative and elusive, but in a regional sense, these ore bodies occur within a belt of northwest-striking faults that have penetrated the crust.

At the Juarez-San Francisco property, pervasively fractured quartzo-feldspathic rocks of Jurassic age (e.g., quartz porphyry and flow-banded rhyolite) provide permeable zones into which mineralizing fluids have been guided. Contacts with more ductilely deformed, phyllosilicate-rich metasedimentary strata create barriers to fluid flow and offer potential traps for ore bodies where appropriately oriented. From my preliminary investigation, I suspect that the gold was originally concentrated within early quartz veins along high-angle faults during Late Jurassic time, then subsequently remobilized and reprecipitated into Laramide thrust zones, probably during a Miocene magmatic event. I recommend more detailed mapping of the stratigraphy and structure with emphasis on locating shallow regions of intersection between the older, high-angle mineralized faults and younger low-angle faults that are oriented favorably to trap ore-bearing fluids remobilized from the deep-seated old faults. Mapping must distinguish
between various generations of faulting and mineralization, with care taken to deduce sense-of-shear on the important fault zones. This work shall assist in identifying and prioritizing key areas to drill and assay. Ideally, geologic mapping and drilling should be coordinated.

Despite the structural complexity apparent at first glance, I am excited about the potential for working out a coherent stratigraphy and structural geometry. These Jurassic rocks provide several marker units, including a distinctive quartz arenite exposed northeast of the Juarez mine, stretched-pebble conglomerate observed at several places, and the Late Jurassic (?) monzodiorite intrusions. Quartz arenite and conglomerate beds have proven to be important stratigraphic markers in the Jurassic sections at Sierra La Gloria (Corona, 1979), Sierra El Batamote (Nourse, 2001), and Sierra La Madera northeast of Magdalena (Nourse, 1995). Also easy to map are the discrete zones of foliation or cleavage (typically developed in the sedimentary protoliths), and breccia zones of large aerial extent that appear to have low-angle geometries. I noticed numerous outcrops where fault striations can provide direction and sense of displacement on major fault zones. One obvious hypothesis to test is whether the San Francisco mine is a displaced extension of the Juarez mine or vice-versa. In northern Sonora, sub-horizontal displacements of several to tens of kilometers along Laramide thrusts or Tertiary detachment faults are commonplace (Corona, 1979; De Jong et al, 1988; Nourse et al., 1994, Iriondo et al., in press).

Given the fact that this property has been mined in several or multiple different stages since initial exploitation by the Spaniards, with more gold produced each time, the probability of discovering new ore bodies or extending existing mines seems great.
Figure 1. Generalized digital geologic map of the Caborca region, showing location of the Juarez-San Francisco property. Geology compiled from De Jong et al., 1988, Jacques-Ayala et al. 1990; Nourse, 2001, and Nourse (unpublished).
Figure 2. Schematic drawing illustrating conjugate fault geometries expected for distinct episodes of Late Jurassic (megashear related) and Late Cenozoic (San Andreas related) strike-slip faulting in western Sonora. $\sigma_1$ and $\sigma_3 =$ maximum and minimum principle stress directions.
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