# FIELD TRIP GUIDE BOOK TO

# NEW IDRIA AREA
# CALIFORNIA

by

R. G. Coleman

14th General Meeting of
the International Mineralogical Association
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R.G. COLEMAN, GEOLOGY DEPARTMENT

STANFORD UNIVERSITY

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# CHAPTER ONE

# PETROGENESIS OF MINERALS IN THE NEW IDRIA AREA AND THE SOUTHERN DIABLO RANGE

## INTRODUCTION

New Idria is one of the best known and oldest mining districts of California. Famous for the quicksilver deposits as well as the rare occurence of the gem mineral benitoite (Louderback, 1905, 1906). The first discovery of pure end member jadeite in North America was was made by Bolander (1950B) along Clear Creek and this was followed by intense mineral exploration that showed the New Idria serpentine mass to contain one of the largest reserves of short fibre asbestos in North America (Merritt, 1962).

The New Idria area is located in the southernmost extension of the Diablo Range of the California Coast Ranges. It still remains one of the most remote and underpopulated areas in central California. Mineral collectors have had continued success in finding new and unusual species in the district where more than 100 different minerals have already been identified (Table 3).

## GEOLOGY AND STRUCTURE

A serpentine mass 19 by 6 kilometers forms the core of a large antiform that lies between the San Andreas fault on the west and the great valley on the east (Fig. 1). Tertiary and Mesozoic sedimentary rocks surrounding the serpentine body have been folded into a series of anticlines and synclines whose axes form acute angles with the northwest trending San Andreas fault. The elongate oval body of serpentine is flanked by the Franciscan assemblage of Early Cretaceous age and the Late Cretaceous Panoche and Moreno formations consisting of marine sandstones and shale (Fig. 8). These Early Cretaceous rocks are often referred to as the Great Valley sequence. Overlying Tertiary marine sediments, as young as Pliocene, are involved in a regional folding event and with the central serpentine mass comprise an aysmmetric anticlinal dome that marks the northern extension of the Coalinga anticline. The contact of the serpentine with the surrounding sediments is marked by high angle faults and shear zones that record upward tectonic movement of the New Idra serpentine mass (Figs. 2 & 3 ). The northeastern contact has been called the New Idria thrust as it overturns the adjacent Mesozoic and Tertiary sediments during its northeastward above them. However the New Idria thrust can not be extended northwest or southeast beyond the perimeter of the dome.

Estimates of the 3-dimensional shape of the New Idria serpentine body have been aided, in part, by gravity and magnetic data (Byerly, 1966, A. Griscom and R. Jachens, U.S.G.S., personal communication). A pronounced negative gravity anomaly (~ 58 mgals) over the serpentine body indicate that it may extend to depths of more than 5 kilometers. Magnetic data is sparse but the anomaly indicates that the body is rootless and probably dips

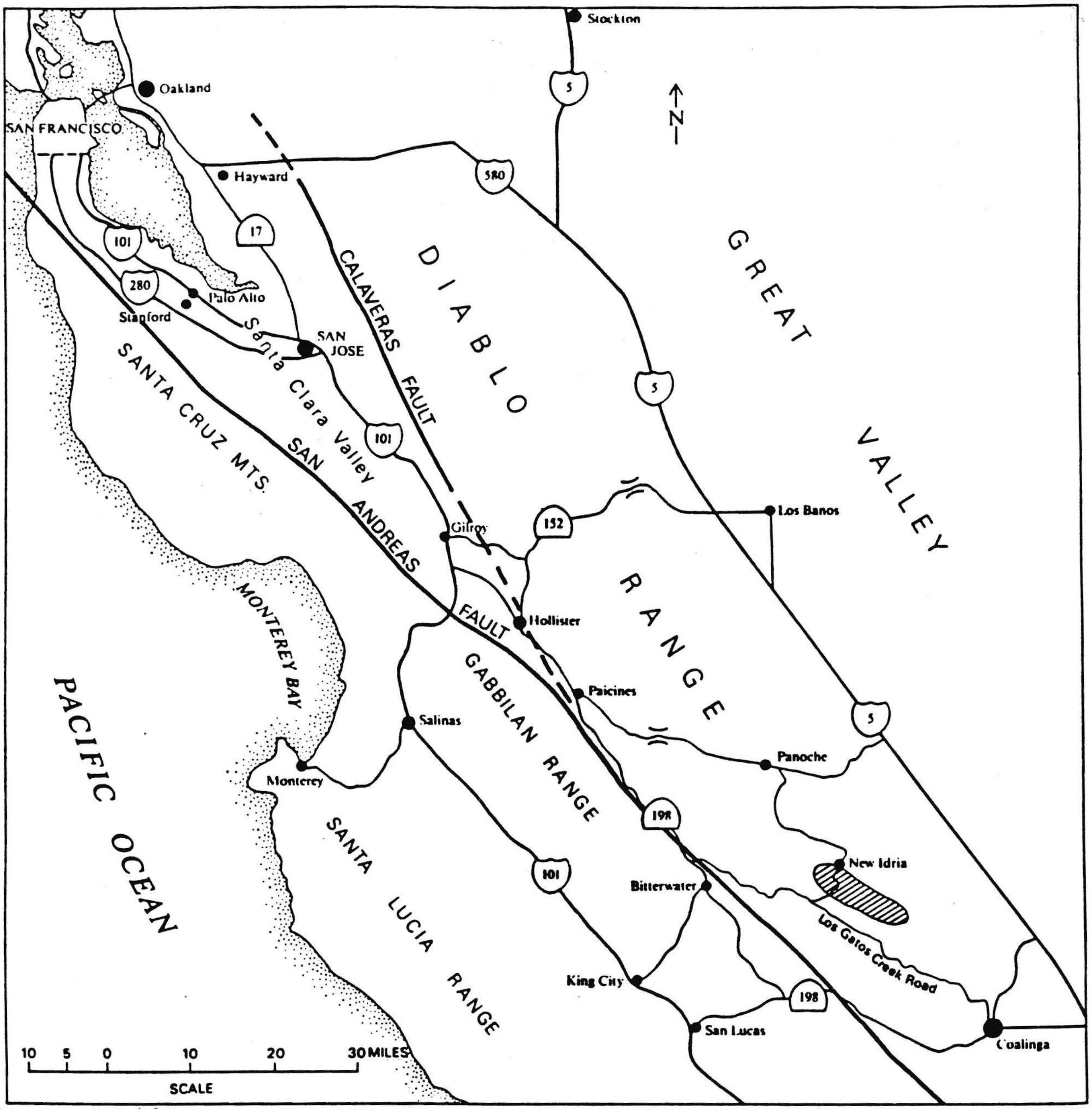


Figure 1. Index map of central California showing some of the major highways and secondary roads along with important geologic features. New Idria serpentine mass shown as area of slanted lines.

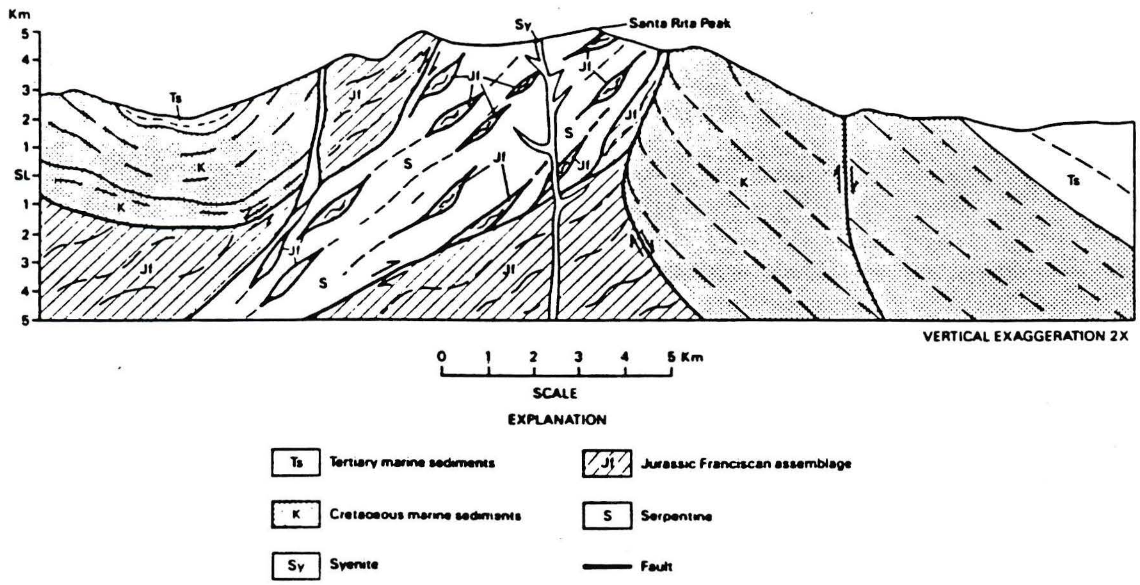


Figure 3. Geologic cross section N-S across the New Idria serpentine mass showing its structural relationships with the surrounding Mesozoic and Tertiary rocks. Geological and geophysical information used for the construction from Coleman (1980), Byerly (1966) and R. Jachens (Pers. communication, 1985).

westerly as a saucer shaped mass (A.Griscom,personal communication (Fig. 3). Recent deep seismic reflection and refraction profiles in the vicinty of Coalinga indicate that packets of Franciscan sediments have been emplaced wedge-like by northeastward thrusting beneath the Great Valley sequence (Wentworth et al, 1984). The structural position of the New Idria serpentine body suggests that it may represent serpentinized peridotites that made up part of the Late Jurassic Pacific oceanic crust. Post Jurassic subduction of this oceanic crust emplaced it under the North American continent where it became underplated beneath the growing Franciscan accretionary wedge (Fig. 3).

## SERPENTINITE

The New Idria serpentinite body (Fig. 2) consists mainly of highly sheared and crushed incoherent fragments of soft, crumbly sheets and clumps of asbestiform material (Mumpton and Thompson, 1975). The serpentine has little strength forming a terrain of low rounded hills composed of flaky and fibrous serpentine minerals with a strong tendency to slide when slopes become oversteepened (Cowan and Mansfield, 1970). Nearly all of the original peridotite protolith has been altered to serpentine minerals, but where olivine and orthopyroxene have survived, their compositon and metamorphic fabrics indicate that they were derived from a depleted tectonite harzburgite or dunite typical of other peridotites in the California Coast Ranges (Loney et al, 1971).

Mineralogical studies indicate that chrysotile-brucite-magnetite are the common products of serpentinization with minor but significant areas of both antigorite and lizardite (Mumpton and Thompson, 1975). Residual tectonic blocks consisting of antigorite-andradite-magnetite indicate that early serpentinization may have taken place under higher temperatures and higher pressures. In fact there is evidence that serpentinization was a continuous process and that each tectonic event provided water and shearing so that the end product was a nearly incoherent mass of flaky serpentine. The widespread occurrence of brucite and its dissolution in the serpentine has produced surface $Mg-HCO_3$ waters. In the weathering zone hydromagnesite, artinite, coalingite, pyroaurite are deposited during the dry periods. At deeper levels the $Mg-HCO_3$ looses some of its bicarbonate and helps in the process of producing low temperature chrysotile in the sheared serpentine.

The serpentine mass has undergone numerous periods of metamorphism during its tectonic movements within the Earth's crust. As a result, serpentine minerals are present that have formed in many different P-T conditions. The coherent antigorite serpentine residual blocks represent deep level serpentinization whereas the pulverant, flaky material formed during shallow tectonic events (Mumpton and Thompson, 1975). Continued tectonic activity in the Tertiary combined with serpentinization has promoted diapiric uprise of the highly sheared and pulverized material. Particulary noteworthy is the occurrence of sedimentary serpentine in the Big Blue Formation of Miocene age

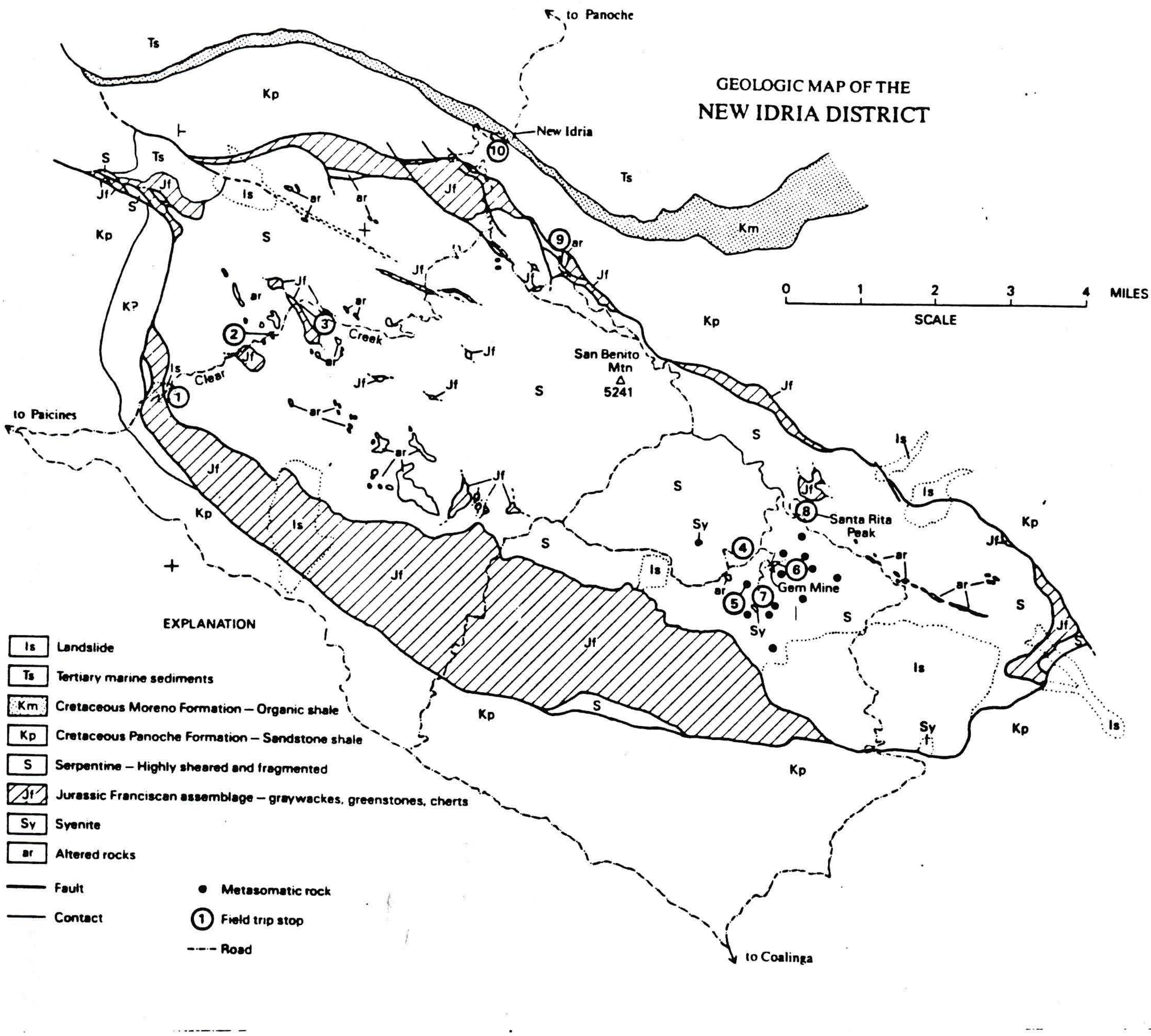


Figure 2. Geologic sketch map of the New Idria district showing major units. Roads to be used on field trip are indicated as well as each field trip stop number. Geology taken from Eckel and Myers (1946), Coleman (1957), and Dibblee (1979).

(Casey and Dickinson, 1976). The Big Blue unit forms part of the east limb of the Coalinga anticline and the source of the sedimentary serpentine was the New Idria serpentine dome as it was breached and eroded in the mid to late Miocene. Other serpentine-bearing sedimentary zones have been reported in the clastic rocks surrounding the dome (Eckel and Myers, 1946).

## TECTONIC INCLUSIONS

Isolated tectonic inclusions of metamorphosed rock ranging in size from 1 meter to 1500 meters show a random distribution within the serpentine. Some of the larger bodies parallel the northwest axial trace of the Coalinga anticline but the smaller blocks have a random orientation (see Fig. 5). Within each separate tectonic block the foliation is internally consistent but there is no correlation of these structures from block to block. Contacts between the serpentine are always sheared and faulted; however, in a few instances calcium metasomatism is developed along a "blackwall" border of the blocks. The actual movement of the tectonic inclusions is difficult to interpret but their emplacement into the serpentine body is later than the serpentinization of the peridotite. Also the metamorphic fabrics seen in the inclusions probably developed before their emplacement. The tabular and elongate shape of the larger inclusions and the vertical foliation combined with their crudely parallel orientation suggest that this alignment may have developed during their upward transport in the plastic serpentine.

The tectonic inclusions within the serpentine represent diverse rock types but they all seem to have been recrystallized under high P/T of the blueschist facies metamorphism. The protolith for nearly all of these inclusions can be traced to the Franciscan assemblage indicating that tectonic emplacement of the inclusions was operative only when the serpentinite was in contact with the Franciscan rocks. In general, the Franciscan metamorphosed tectonic inclusions are derived from mafic volcanics and pyroclastics, graywackes, and cherts. Glaucophane, lawsonite, pumpellyite, albite, chlorite, and stilpnomelane are the characteristic blueschist minerals within the tectonic inclusions. The metagraywackes are characterized by the assemblage quartz-albite-crossite-chlorite-stilpnomelane and the metabasalts contain albite-pumpellyite-lawsonite-chlorite-sphene. An unusual metasediment has the assemblage albite-crossite-acmite-stilpnomelane and it is within these tectonic blocks that veins of pure jadeite are found. Even though impure jadeite (jd 80 di 20) is common in the quartz-bearing graywackes of the southern Diablo Range, none of these rocks occur as tectonic inclusions within the serpentine mass.

Formation of pure jadeite within the New Idria serpentine mass is restricted to tectonic inclusions containing albite-crossite-acmite-stilpnomelane schist and in smaller pods of impure jadeite that are found near the boundaries of the larger tectonic inclusions. These albite-crossite schist bodies have unusual quantities of sodium (9.8 % $Na_2O$) and appear to be desilicated keratopyhric pyroclastics. The emplacement of these meta-keratophyric rocks into the New Idria serpentine mass at depth provided a situation where it was possible for them to loose silica into the surrounding serpentine. The presence of actinolite-chlorite "blackwall" reaction zones around some of these bodies provides evidence of this deslication process. During this desilication process fluids near the composition of pure jadeite developed in extension veins. The pressure and temperature required for pure jadeite to form in the absence of quartz is perhaps the key factor in allowing monomineralic pods and veins of jadeite to form. The stability of jadeite in a silica deficient environment is limited by the reaction:

$$\underset{\text{jadeite}}{2NaAlSi_2O_6} = \underset{\text{nepheline}}{NaAlSiO_4} + \underset{\text{albite}}{NaAlSi_2O_8} \quad (1)$$

The equilibrium curve for this reaction has been determined by experimental results (Robertson et al., 1957) and from the thermodynamic values on the components of reaction (1) (Kelly et al., 1953; Kracek et al, 1951; Wood et al., 1980). The conditions for the formation of jadeite in the New Idria serpentine mass using these parameters is probably ~ 5 kb and 300°C. The temperature is controlled by the presence of analcite instead of nepheline and the association of hydrogarnet in the calc-silicate rinds (Coleman, 1961).

It is interesting to note that there are only five other known localities of pure massive jadeite in the world and in each case these occurrences are found within tectonic blocks contained within serpentine and associated quartz-free albite-rich rocks.

Motagua Valley, Guatemala, Foshag (1957)
Pai-yer massif, Polar Urals, USSR, Dobretsov (1984)
Kenterlaus massif, Prebalkash, USSR, Drobetsov (1984)
Taumau, Burma, Bleek (1907)
Omi-Kotaki, Honshu, Japan, Chihara (1971)

The structural setting of the New Idria serpentine mass indicates that it was part of an oceanic crustal sequence upon which the Franciscan sediments were deposited. Mesozoic plate convergence produced subduction zones where the peridotite became serpentinized and the surrounding Franciscan sediments and volcanics were subjected to de-watering and eventually recrystallized under high P/T gradients. Tectonic movements allowed tectonic blocks of the metamorphosed Franciscan to become incorporated into the serpentinized peridotite. De-silication within this high P/T regime allowed fluids of jadeitic compostion to develop within the tectonic inclusions filling extension veins. Post-metamorphic tectonism forced the serpentinite to rise to a higher level into the crust carrying with it the jadeite-bearing tectonic inclusions that had been incorporated earlier. Throughout California within the Franciscan terrane there is a very close association between the high grade tectonic blocks of eclogite and gneissic glaucophane-garnet-epidote within the tectonized serpentinite bodies. Further reinforcing the importance of serpentinite as a medium of tectonic transport.

## INTRUSIONS AND METASOMATISM

Restricted plug-like intrusions of syenite are found clustered in the southern half of the New Idria serpentine body (Fig. 2 and Table 1). These rocks consist mainly of barkevikite soda syenite with very minor amounts of camptonite and albitite. The coarse-grained, porphyritic to pegmatitic facies contain large prisms of barkevikite up to 6 inches long. The syenite consists predominately of plagioclase and barkevikite with minor amounts of muscovite and sphene. The feldspar in these rocks is usually deuterically altered from andesine to albite with large areas of feldspar being replaced by natrolite and analcite. Along the contact are small chill zones consisting of camptonite that has a basaltic composition containing olivine, clinopyroxene, plagioclase ($An_{20-69}$) and barkevkite. Other contacts contain selvages of albitite that apparently formed as a result of contact metasomatism. No age determinations are available but these intrusives are probably related to the Late Tertiary basalts found sporadically within the Diablo Range (Johnson and O'Neil, 1984). At least some of these rocks reported from the Diablo Range are alkaline olivine basalts containing mantle xenoliths (Nakata,1977). It is thought that these mafic-syenite intrusions were the source of hydrothermal fluids that produced an unusual array of metasomatic bodies within the serpentine (Coleman, 1957). The unique petrologic nature of the Tertiary syenite-camptonite intrusions within the New Idria mass is probably the result of reaction and contamination of the olvine alkaline basalts as they invaded the water-rich sheared serpentine.

### Metasomatic Bodies

Nearly 30 small repacement bodies have formed in the serpentine within a radius of about 1.5 miles from the Tertiary syenite-camptonite intrusions (Fig. 2). They form small veins up to six inches wide and as discontinuous replacement zones in the serpentine up to 6 feet wide and 10's of feet long. These same veins and metasomtic zones are also present within tectonic inclusions derived from the Franciscan. An amazing array of beautiful calc-silicate and barium-titanium minerals have developed in the veins of these replacement bodies. It is these occurrences that have made New Idria such a mecca for mineral collectors.

These metasomatic rocks are divided into three different types based on their mineralogy:

1- Chlorite rocks containing garnet, perovskite, and titanium-rich silicates.
2- Diopside-chlorite rocks containing vesuvianite, garnet, magnetite.
3-Natrolite-crossite rocks containing benitoite, neptunite, joaquinite and others.

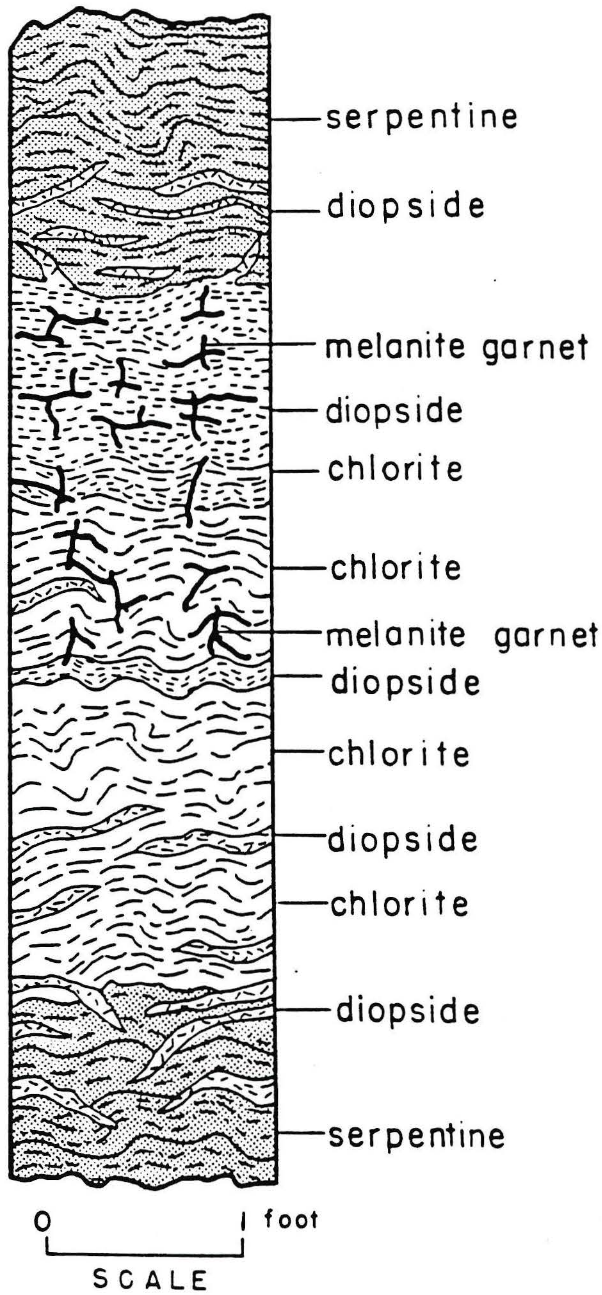


Figure 4. Section through a diopside-chlorite metasomatic body replacing serpentine. Located at field stop number 5 (see Fig. 6) in Chap. 2.

TABLE 1 Chemical analyses of syenite and camptonite.

| | 1 | 2 | 3 |
|---|---|---|---|
| $SiO_2$ | 48.96 | 51.42 | 60.00 |
| $TiO_2$ | 2.01 | 2.20 | .42 |
| $Al_2O_3$ | 15.72 | 16.58 | 16.88 |
| FeO | 9.65 | 7.62 | 3.02 |
| $Fe_2O_3$ | .36 | 1.48 | 1.83 |
| MnO | .17 | .23 | .12 |
| CaO | 7.76 | 6.77 | 3.16 |
| MgO | 6.52 | 3.68 | 1.40 |
| $K_2O$ | .75 | 1.06 | .94 |
| $Na_2O$ | 5.22 | 6.04 | 9.31 |
| $H_2O-$ | .42 | .34 | .43 |
| $H_2O+$ | 2.29 | 1.41 | 1.53 |
| ZrO | - | - | .03 |
| BaO | .05 | - | .06 |
| SrO | - | .08 | .02 |
| $P_2O_5$ | - | .49 | .14 |
| $CO_2$ | - | .45 | .59 |
| Total | 99.88 | 99.85 | 99.88 |

1- Camptonite (Coleman, 1957)
2- Syenite (Coleman, 1957)
3- Syenite (Arnold and Anderson, 1910)

The chlorite-rich metasomatic zones are discontinuous tabular bodies that have a definite replacement contact with the sheared serpentine. The relpacement is predominately chlorite after serepentine forming a rock with a light greenish to blue color which has a pronounced foliation produced by the chlorite and garnet or sphene bands. The chlorite is mainly clinochlore associated with an andradite garnet. These rocks are either porous or vuggy with many fractures. In the late stage of metasomatism the voids are filled with beautiful crystals of melanite, magnetite, perovskite, vesuvianite, diopside, apatite, zircon, rutile. and chevkinite. These late forming minerals are usually Ti-rich or Ti-bearing. The variation in titanium content produces strong zoning in both the garnets and sphene.

The diopside-chlorite metasomatic zones have the same tabular shape and size as the chlorite-rich bodies. They also exhibit a crude foliation but their color is much lighter and may have zones of a creamy color. Clinochlore and pure diopside are the main phases replacing the serpentine. Figure 4 details the structure and mineral distribution of a single body. At the contact, stringers of diopside form along the sheared serpentine and directly replace antigorite. Alternating zones of chlorite and diopside display minor folding and fractures are filled with andradite-melanite garnets and prismatic crystals of diopside. Less abundant are perovskite, vesuvianite, and magnetite. The chemical changes brought about by metasomatism are illustrated in Table 2 where the average serpentine is compared to a calc-silicate body. It is readily apparent the fluids causing the replacement had to contain Ca, Fe, Al, and Ti with removal of Si, Mg, and hydrogen ion.

The spectacular benitoite-neptunite-natrolite veins are found in a Franciscan tectonic inclusion consisting of albite-crossite-epidote schist associated with metagreenstone and metagabbro. The elongate zone of metasomatism is contained wholly within the albite-crossite-epidote schist. This zone consists of drusy natrolite impregnated with fibrous crossite. The open and vuggy parts of the vein are pure white natrolite containing perched crystals of benitoite and neptunite with minor joaquinte and other minerals. A similar host rock is seen on Santa Rita Peak where Joaquinite has been found. Since the early discovery of benitoite (Louderback,1907) it was thought to exist only at this one locality; however, there have been recent finds of benitoite in other parts of California.

The unusual metasomatic rocks of the New Idria district are unique in their occurrence. The process of "rodingitization" could perhaps be called on to produce the calcium-rich rocks ; however, the replacement rocks show no relict structures characteristic of rodingites as they are usually derived from pre-existing mafic igneous rocks. The existence of titanium minerals, zircon, apatite, and others not commonly found in serpentinized peridotites suggests that fluids responsible for the metasomatism came from a source other than those normally generated during serpentinization (Barnes and O'Neil, 1969). The clustering of these metasomatic bodies around the syenite-camptonite intrusions as well as the apparent depletion of Ca, Mg, Fe, Si, and Ti with concomitant enrichment of sodium in the

TABLE 2. Serpentine to calc-silicate metasomatic chemical changes.

| | SERPENTINE WT.% | SERPENTINE CATIONS | CALC-SILICATE WT.% | CALC-SILICATE CATIONS |
|---|---|---|---|---|
| $SiO_2$ | 41.47 | 35.6 | 34.69 | 33.0 |
| $Al_2O_3$ | 1.35 | 1.4 | 10.72 | 12.0 |
| FeO | 5.57 | 4.0 | 9.76 | 7.7 |
| $Fe_2O_3$ | 2.62 | 1.7 | 4.52 | 3.2 |
| $TiO_2$ | .04 | - | 1.90 | 1.4 |
| MnO | .24 | .1 | .27 | .2 |
| CaO | - | - | 12.33 | 12.5 |
| MgO | 36.03 | 46.0 | 18.46 | 26.0 |
| $K_2O$ | - | - | .05 | - |
| $Na_2O$ | - | - | .08 | - |
| $H_2O+$ | 12.05 | 34.3 | 6.88 | 21.8 |
| $H_2O-$ | .76 | - | .39 | - |
| $CO_2$ | - | - | - | - |
| | 100.13 | | 100.04 | |

SERPENTINE ALTERS TO CALC-SILCATE

By adding:
0.1 ions of Na
12.5 ions of Ca
0.1 ions of Mn
1.4 ions of Ti
5.2 ions of Fe
10.6 ions of Al

By subtracting:
20.0 ions of Mg
2.6 ions of Si
25.0 ions of H

alkali syenite suggests that the source of the fluids was from the intrusion (Coleman, 1957).

The titanium-rich silicates from the Gem Mine pose a special problem as here the mineralogy is distinct from the other metasomatic bodies. Particulary puzzeling is the source of the barium to form the benitoite and the high concentration of rare earths in joaquinite. Neither the intrusive nor the serpentine contain unusual barium contents nor were barium minerals found within the calc-silicate or chlorite metasomatic bodies. The most likely source of the barium is from the meta-sediments within the Franciscan where barium-rich zones may have been mobilized during metasomatism. The high sodium at the Gem Mine is part of the de-silication of the albite-crossite-epidote schist similar to that described at the jadeite locality. Significantly benitoite, neptunite, and joaquinite have more recently been described from the Victor Claim located near Clear Creek (Millage, 1981). The preservation of all the delicate drusy mineral occurrences within all of the metasomatic bodies indicates that the mineralization was very late and has not been affected by strong tectonic movements.

## CINNABAR MINERALIZATION

The cinnabar deposits of the New Idria district are contained in altered rocks clearly related to the New Idria serpentine mass. The most spectacular host rocks are the silica-carbonate rocks which form elongate zones within the serpentine. These striking reddish-brown silica-carbonte replacement zones develop rugged porous outcrops along shear zones within the serpentine. The resistant silica-carbonate rocks form erosional remnants that contrast starkly with the soft greenish-white sheared serpentine.

These silica-carbonate rocks are formed by direct replacement of serpentine by acidic $CO_2$-rich hydrothermal fluids of low temperature (Barnes et al., 1973). These fluids are probably derived from the surrounding sediments heated by the Miocene-Pliocene volcanics mentioned earlier. The silica-carbonate rocks contain variable amounts of quartz, chalcedony, opal, associated with carbonates (magnesite, dolomite, ankerite, and calcite). Minor amounts of iron sulfides and cinnabar often are accompanied by hydrocarbons.

The mercury deposits from the silica carbonate rock have produced much less ore than those in the New Idria mine area where the main ore bodies are hosted in altered shale and sandstone along the New Idria thrust. Here the thrust has overturned the Panoche Formation and the alteration and cinnabar mineralization was confined to a narrow zone where Franciscan graywackes are in contact with the Panoche sediments (Eckel and Meyers, 1946).

The ore-bearing Panoche sediments are hydrothermally altered and have a bleached appearance. Considerable fracturing of these sediments along the thrust provided a permeable zone for the ascending mineralizing fluids. The sedimentary rocks became indurated, in part, by introduced silica and by recrystallization of the sedimentary quartz grains. Pyrite with minor amounts of marcasite develop in veins and as cement within the altered rocks usually making up several percent of the rock. Cinnabar is contained within the veins and may form a breccia cement.

These hydrothermal fluids may have been the same acidic $CO_2$-rich fluids that produced the silica-carbonate rock within the serpentine. However, within the shales and sandstones of the Panoche Formation the low activity of both Ca and Mg prevented development of carbonates and instead only minor silicification accompanied the deposition of the cinnabar.

It appears that fluids depositing the mercury deposits were distinct and different from those producing the calc-silicate metasomatites and the Gem mine benitoite deposits although it is possible that the heat source for both of these areas can be related to the Miocene-Pliocene volcanics of the southern Diablo Range. The recent association of gold with mercury deposits in California has renewed interest in deposits such as New Idria, However no information is available on the gold contents of the New Idria deposits (Vredenburgh, 1982)

# CHAPTER TWO

## DESCRIPTION OF FIELD TRIP STOPS

### INTRODUCTION

This section is designed as a general guide for those participants on the IMA field trip but can also be used as a guide for anyone interested in the New Idria area. The field trip will encompass three days with overnight lodging in Coalinga. Nearly all of the stops will be within the New Idria serpentinite mass except for the afternoon of the thrid day will be spent inspecting the Franciscan blueschist along Panoche Pass road.

### STANFORD-HOLLISTER

The trip will start from the Geology Corner on the Stanford University Campus. Freeway 280 south can be entered from Page Mill or Sand Hill roads both accessible from Junipero Serra Blvd. bordering the Stanford campus on the southwest. Follow 280 south 20 miles until it intersects Highway 101 at San Jose. From this junction approximately 52 miles south of Stanford take Highway 25 to Hollister (Fig. 1).

During this first part of the trip you will follow the Santa Clara Valley bordered on the east by the Diablo Range and on the west by the Santa Cruz Mountains. The San Andreas fault trace occupies a narrow zone along the base of the Santa Cruz Mountains and eastward the Hayward-Calaveras fault follows the foothills of the Diablo Range.

Hollister is 12 mile south of the junction with Highway 101 and Highway 25 and occupies ground that is directly on the Calaveras fault. Right lateral displacements are found on streets and their curbs as continued creep along the fault offsets man-made structures in the city.

### HOLLISTER-CLEAR CREEK

Follow Highway 25 south through Hollister to Tres Pinos. On the left the Gabilan Range consisting of granite and associated metamorphic rocks is being uplifted along the San Andres fault. The Santa Clara Valley narrows into the San Benito River Valley and where the topography is controled by the San Andreas fault (Fig.1) .

At Paicines, continue south along Highway 25 for approximately 32 miles to the Bitterwater junction. Just south of Paicines, vineyards along the valley are those of the Almaden Winery. As the San Benito Valley narrows, 10 miles south of Paicenes, large landslides in Tertiary sediments are seen on the left side of the road. Marble and other metamorphic tectonic blocks within the San Andreas fault zone stand out along the road in this same area. Shutter ridges, sag ponds, disrupted drainage are common along this stretch of road.

Eastward from the bitterwater junction along the Coalinga-Los Gatos road exposures are mostly Pliocene marine sediments of the Etchegoin Formation and where serpentine outcrops it marks northwestern trending strike-slip faults related to the San Andreas fault system (Fig.8).

## CLEAR CREEK TRAVERSE

At the Clear Creek junction turn left and cross the San Benito River bed beyond this point the road is unpaved and very rough. Note the mortar beds developed within the dry stream as a result of bicarbonate-rich waters draining the New Idria serpentine mass.

### Stop 1

Contact between the New Idria serpentine mass and the Franciscan formation of Jurassic age about 2.9 miles from the Clear Creek junction (Jade Mill road) (Fig. 2). The serpentine forms subdued topography and has a tendency to slide. The Franciscan rocks consist mainly of graywacke and form prominant ridges outlining the western border of the serpentine body at this locality. The Franciscan and overlying Gravelly Flat and Panoche Formations of Cretceous age dip steeply to the west. The contact is tectonic and shows shearing and faulting. The serpentine consists mainly of highly sheared flaky chrysotile. On the weathered surfaces nodular hydromagnesite can be seen in the stream banks and road cuts and the reddish stain is due to iron oxides and sometimes coalingite.

This contact demonstrates very well the tectonic relationships between the New Idria serpentine body and the surrounding sedimentary rocks. The outcrop pattern of the serpentine body is domal with the dips of the flanking sediments away from the contact. Upward diapiric movement of the serepentine during many tectonic events has allowed it to rise into and above the enclosing sediments forming the core of the Coalinga anticline (Fig. 3).

### Stop 2

Silica-carbonate rock (listvinites) forms distinctive, reddish-brown outcrops that have a porous texture and appear to follow major shear zones in the serpentine. Exposures of silica-carbonate 5.4 miles above the Clear Creek junction are related to cinnibar mineralization in this areas (Fig. 2). Silica-carbonate rocks are composed mainly of quartz, chalcedony, opal, ankerite, magnesite, dolomite and rarely calcite. Iron oxides often stain the outcrop where sulfides have been leached and oxidized. Acidic $CO_2$-rich hydrothermal fluids react with serpentine to form these replacement bodies. Such fluids often contain mercury and most of the cinnabar deposits of the New Idria district are related to alteration zones within or on the perimeter of the serpentine body. Specimens from this locality can be found that show a gradation from serpentine to a porous rock that is mostly quartz-chalcedony-opal-carbonate. Near the margins of the silica-

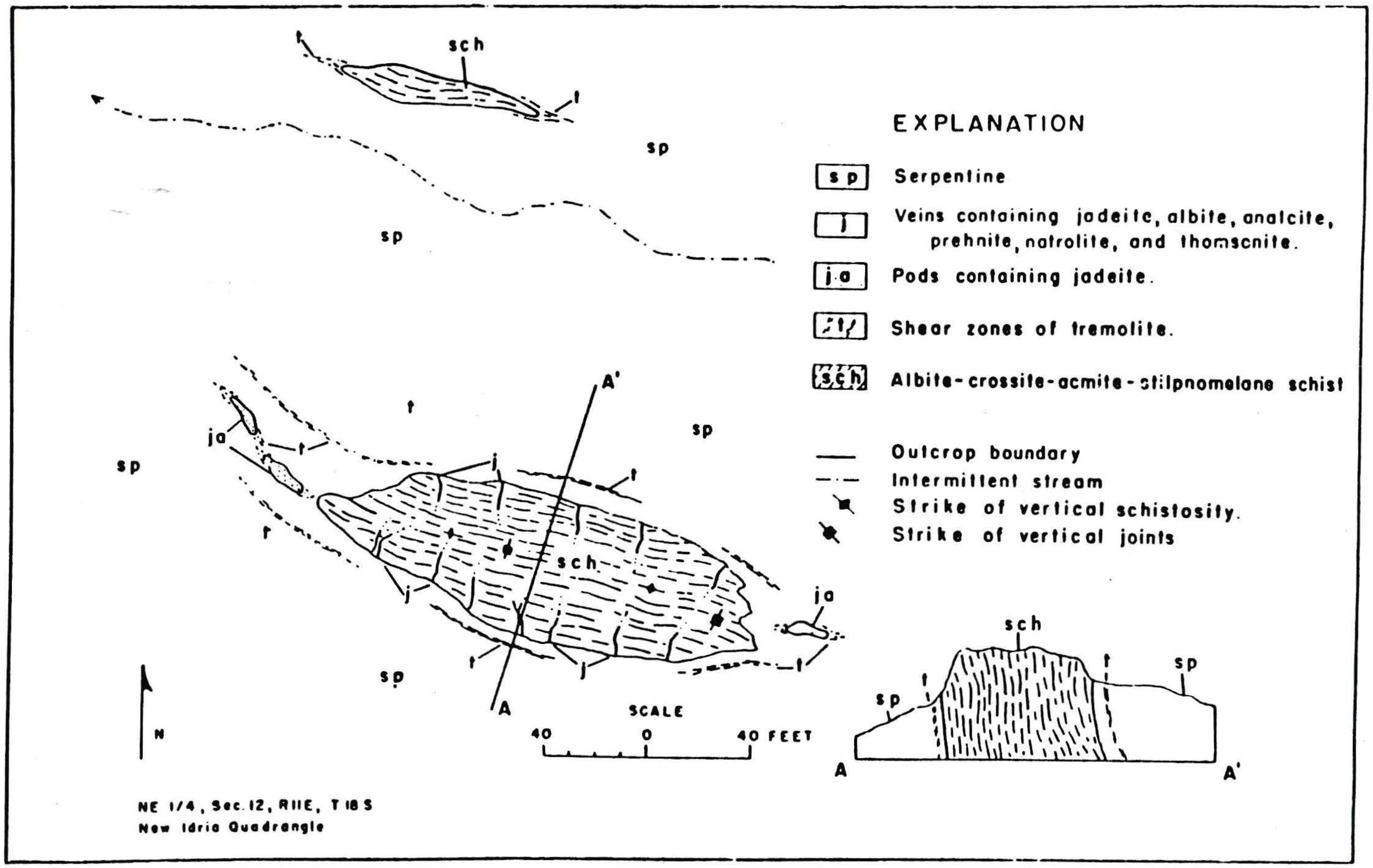


Figure 5. Jadeite-bearing tectonic inclusion of schist along Clear Creek. Field stop number 3 shown in Figure 2.

carbonate bodies serpentine textures are preserved and relict grains of chromite can be recognized. The bright green material is mostly chalcedony or opal.

Stop 3

Jadeite-bearing tectonic inclusions of schist are found within serpentine where Clear Creek narrows 7.5 miles above the Clear Creek Junction(Figs. 2 & 4). Here a prominant craggy outcrop within the serpentine on the left side of the road consists of metasediments derived form the Franciscan Formation. The distribution of the tectonic inclusions is entirely random although their internal foliations and lineations are consistent and penetrative. Contacts between the enclosing serpentines and inclusions are sheared and faulted. Tremolite or chlorite are present at some contacts and rodingite zones are found in the smaller tectonic blocks. Multiple tectonic movements of the serpentine mass obscure the original structural relationships, however, the field relations indicate that the inclusions were incorporated into the serpentine body after it had become almost completely serpentinized.

The inclusion has a penetrative cleavage parallel to original bedding with some isoclinal folding. The schist is a fine-grained bluish-gray rock consisting of albite-crossite-acmite-stilpnomelane without any quartz. Fractures developed normal to the cleavage contain pure jadeite, jadeite-albite, albite-natrolite-thomsonite, pectolite, and analcite. The jadeite in these veins is nearly pure jadeite coexisting with albite and in some areas being replaced by analcite. This occurrence of jadeite was first reported by Bolander (1950B) and is quite similar to occurrences of pure jadeite from Guatemala; Kotaki, Japan; Tawmaw, Burma; and Russia.

Pods of green jadeite associated with the larger inclusions develop nearly monomineralic bodies of impure jadeite (Jd 70%) and appear to have inherited the metamorphic banding of the protolith schists. Veins of jadeite are not found within the serpentine and it is assumed that fluids responsible for the production of jadeite resulted in the de-silication of keratophyric volcanic rocks (Coleman, 1961). All of the relations described here will be observed at this stop and collections can be made.

Return down the Clear Creek Road to the Coalinga-Los Gatos Road and turn left. Coalinga is approximately 36 miles from this junction.

## COALINGA-KCAC ASBESTOS MINE (SECOND DAY)

On leaving Coaling follow Highway 33 north to Three Mile Corner and turn left on Gale Avenue for 2 miles and then turn right on Derrick where one mile north the Los gatos Creek Road begins. Follow the Los Gatos Creek Road 23 miles north to the KCAC asbestos private haulage road (Fig. 2). This is a locked gate and permission is needed to traverse this road.

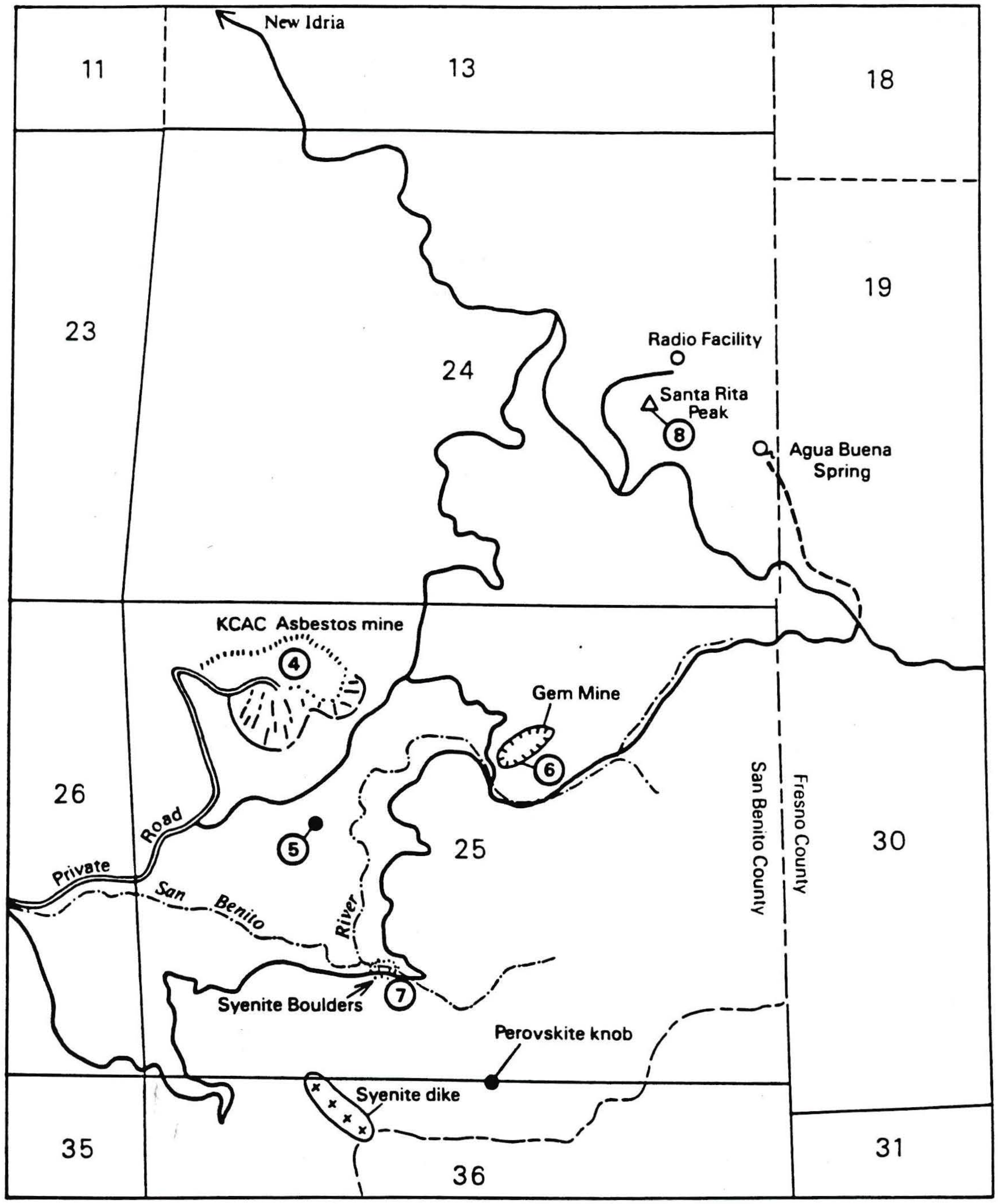


Figure 6. Sketch map showing roads and locations of field trip stop numbers 4 to 8.

Coalinga is situated in an active oil producing area which was first discovered in 1890. The Coalinga anticline is the main structure influencing the development of oil traps and extends northwestward where it is breached by the New Idria serpentine body. The Los Gatos road north from Coalinga traverses the Tertiary marine sediments and the thick section of the Upper Cretaceous Great Valley marine sandstones and shales of the Panoche Formation. These sediments have been folded into the White Creek syncline whose fold axis is parallel to that of the Coalinga anticline. The KCAC private haulage road crosses the east limb of the White Creek syncline and traverses west dipping Panoche and Franciscan sediments. These sediments are in thrust contact with the New Idria serpentine body in the same fashion as seen along the Clear Creek traverse(Fig.2). The haulage road then follows along the San Benito River headwaters until it reaches the open pit asbestos mine (Fig.6).

Stop 4

The KCAC asbestos open pit operation was initially developed by Union Carbide (Fig. 6). A sampling and drilling program commenced in 1959 and led to production from their plant in King City by 1963. Two other open pit and milling plants were developed by the Coalinga Asbestos Company and Atlas Minerals Company both of whom started production of short fibre asbestos in the early 1960's.

The ore is mined by open-pit methods because of its soft and incompetent nature. The best asbestos ore is in the southeastern part of the serpentine body. The ore consists of incompetent masses of sheared serpentine fragments and fibre plates interspersed with sub-rounded tectonic blocks of massive serpentinized peridotite. An oxidized zone 15 to 30 feet develops at the surface and the tectonic blocks are decomposed to a reddish-brown earthy material producing crumbly masses surrounded by the sheared serpentine.

The mineralogy of the asbestos deposits has been carefully documented by Mumpton and Thompson (1975). The massive, dense, and hard tectonic blocks (5-10 meters) of serpentine that are pushed into the spoils pile consist mainly of chrysotile-antigorite-lizardite-brucite-magnetite and are typical of the unweathered serpentinized peridotites that make up most of the New Idria serpentine. Nearly all of these blocks contain trace amounts of josephinite (FeNi) as a product of serpentinization. The protolith for these rocks are dunites and harzburgites commonly found in the Franciscan (Loney et al, 1971). Thin films of mountain leather up to several square feet form as shear surfaces on these tectonic blocks and consist mainly of chrysotile. The main ore consists of brittle blades and plates of green serpentine of variable size (1 cm to 10 cm) mixed with friable agglomerates of powdery chrysotile. According to Mumpton and Thompson (1975) the chrysotile fibres are very short (several microns) forming a swirling mesh or disoriented and tangled fibres. The recoverable fibre content of the ore varies from 35-75 percent with the end product having a remarkable surface area which averages(80 $m^2/g$). Ferroan brucite ranges from 7-8 percent in all of the serpentinized material below the oxidized zone where the serpentine contains as much as 15% iron.

In the surface weathering zone the brucite is unstable and breaks down in the presence of $CO_2$ bearing meteoric waters. Surface coatings of artinite and hydromagnesite are typical in the sheared areas. The weathered tectonic blocks commonly contain pyroaurite and coalingite with amorphous hydrated iron oxide. Mumpton and Thompson (1975) suggest that the intense shearing of the serpentinite by meteoric ground waters has allowed chrysotile to be precipitated on all surfaces within the sheared mass. The presence $Mg^{+2}$-$HCO_3^{-1}$ waters in the New Idria body indicates that dissolution of serpentine and brucite is now taking place with introduced meteoric waters. Magnesium carbonates precipitate in the weathered zone whereas magnesium-rich waters below the water table where $HCO_3^{-1}$ is less abundant may lead to precipitation of chrysotile serpentine or reaction with the earlier formed antigorite or lizardite (Barnes and O'Neil, 1969). Thus the unique tectonic setting of the New Idria serpentine body has allowed wholesale formation of micron size chrysotile fibres. Collection of all of the above mentioned minerals is possible within the KCAC open pit mine.

## CALC-SILICATE METASOMATITES AND GEM MINE

On leaving the KCAC asbestos pit follow the paved road down to the stream valley (0.3 mile) and the turn left on to a dirt road that crosses the stream and climbs the low ridge to the east of the pit. At the crest of the ridge turn right and park along the ridge road (Fig. 6).

### Stop 5

A tabular calc-silicate body forms several small craggy outcrops along the ridge (Fig. 6). This body is much more resistant to erosion than the surrounding sheared serpentinite and affords an excellent exposure. Within the serpentine body there are numerous zones that have formed by metasomatism of the serpentine or the tectonic inclusions. These rocks contain a suite of calc-silicate and titano-silicate minerals. Nearly all of these unusual mineral occurrences are found in this general vicinity related to a small barkevikite syenite intrusion.

At this locality, the tabular body consists mainly of pure diopside and chlorite forming a layered and foliated rock. At the top of the tabular body diopside forms replacement stringers into the serpentine accompanied by andradite in the vuggy areas(Fig. 4). At the contact zone there is a gradual change from diopside-serpentine to diopside-chlorite. Within this folded part vertical fracturers develop and these are filled by beautiful drusy surfaces of andradite and melanite garnet containing radiating clusters of pure white diopside. Color changes from white to green in the foliated metasomatic body represent chlorite and diopside rich replacement zones. The lower contact grades into serpentine with diopside stringers similar to that seen at the top contact. The metasomatic replacement of serpentine at this locality was accompanied by deformation and fracturing, but late stage mineralization continued beyond deformation healing the earlier formed fractures. Titanium apparently was introduced in the late stages as the melanite garnets show zoning that indicates increasing tiatanium contents towartds the rim of the individual crystals.

Stop 6

The benitoite Gem Mine is reached from Stop 5 by following the ridge road north 0.2 miles where it intersects with the main Gem Mine road (Fig. 6). Turn right and follow the road 0.3 miles until you reach the San Benito River headwaters. Here is a large flat area for parking. The Gem Mine is private property and permission to collect is required from the owner.

The Gem Mine is the most famous mineral locality of the New Idria area and has produced spectacular specimens of blue benitoite and dark reddish neptunite implanted on pure white natrolite. The minerals of this locality were first meticulously described by Louderback (1907,1909) and W.W. Goldschmidt had commented that these were probably the best described new minerals he had seen up to that time. The Gem Mine is situated within a large tectonic inclusion of Franciscan now consisting of greenstone, gabbro, and albite-crossite-epidote schist forming a small ridge cut by the San Benito River headwaters. The zone of metasomatism containing the benitoite-neptunite-natrolite veins is entirely within the schist portion of the inclusion. The zone is elongate and consists of many irregular natrolite veins. The rocks in the altered zone are vuggy and porous impregnated with natrolite forming nodular masses of natrolite and crossite. Veins of pure white natrolite form granular aggregates projecting inward producing cockscomb drusy surfaces. The center of these natrolite veins maybe open and vuggy or totally filled. Implanted on the open drusy natrolite are euhedral crystals of blue pyramids of benitoite and brilliant, reddish-brown crystals of neptunite. Joaquinite is extremely rare and always present as small honey-yellow crystals up to 2 mm. Greenish clots on the surface of the natrolite are composed of cores of djurelite surrounded by an alteration halo of chrysocolla.

Stop 7

Barkevikite syenite intrusions are found in the vicinity of the Gem Mine and are considered to be the cause of the unuusual metasomtic bodies of this area. Follow the road along the left bank of the San Benito River headwaters about 0.9 miles where a pile of huge boulders of syenite are available for collecting (Fig. 6). The syenite is mottled brown and white with large prisms of barkevikite set in a white groundmass of feldspar. In most cases, the igneous feldspars have been altered to albite-natrolite-analcite mixtures as a result of deuteric alteration. Where the contact between the serpentine and the syenite can be seen selvages of albitite are found indicating strong reaction with enclosing serpentine. Chilled margins of camptonite are rarely found but point to the possibility that the original magma may have been an alkali basalt. Chemistry of these rocks show that they are undersaturated and contain normative nepheline. The associated metasomatic rocks show enrichment in Al, Ca, Fe, Ti and trends in the alteration of the syenite to albitite indicate that these same elements may be liberated and thus develop fluids capable of metasomatizing the serpentine.(Table 2).

## SANTA RITA PEAK

Stop 8

Santa Rita Peak is reached by retracing the route to the Gem Mine and following the road up to the intersection with the Spainish Lake-New Idria (1.7 mile) Road. Turn right and follow the road south to the next junction at the saddle and then turn left and follow the road to the radio repeater station (Fig. 6). The brownish-red rocks of Santa Rita Peak (5165 feet) consist of antigorite and andradite (pale yellow topazolite) with some veins of pale actinolite . The peak is surrounded by sheared soft flaky serpentine and is interpreted as an earlier formed serpentine mass that now represents a large resdual tectonic block. The view from Santa Rita peak reveals the contact along the northeastern edge of the serpentine body as well as the east dipping Cretaceous Panoche sandstones and shales. Further to the east steeply dipping Tertiary marine sediments overlie the Cretaceous sediments. On a clear day the San Joaquin valley can be seen and beyond that some 100 miles to the east is the Seirra Nevada crest. Return to the KCAC asbestos haulage road and drive to Coalinga.

## COALINGA-NEW IDRIA (THIRD DAY)

Take the Los Gatos Road from Coalinga to the Clear Creek junction (31.1 miles) and turn right(Fig. 1 & 2). Take the Clear Creek Road east 14 miles to New Idria. The New Idria mining district was third in its total production of quicksilver in the United States. Following its discovery in 1853 production between 1858 and 1944 amounted to 437,195 flasks (One flask = 75-76 lbs) with a value of 31 million dollars. Following World War II production was sporadic and the mines closed in 1972.

The mercury deposits, as described by Eckel and Myers (1946), consist mainly of cinnabar which is concentrated in veins and stockwork within altered serpentine and sediments. The altered rocks are mostly shales of the Panoche formation where ore depositon in these rocks is controled by changes in the strike and dip of the faults. The major structural feature of the ore deposits is their clear association with the New Idria thrust which bounds the northeastern margin of the serpentine body (Fig. 7) . Broken and sheared slices of Franciscan graywacke

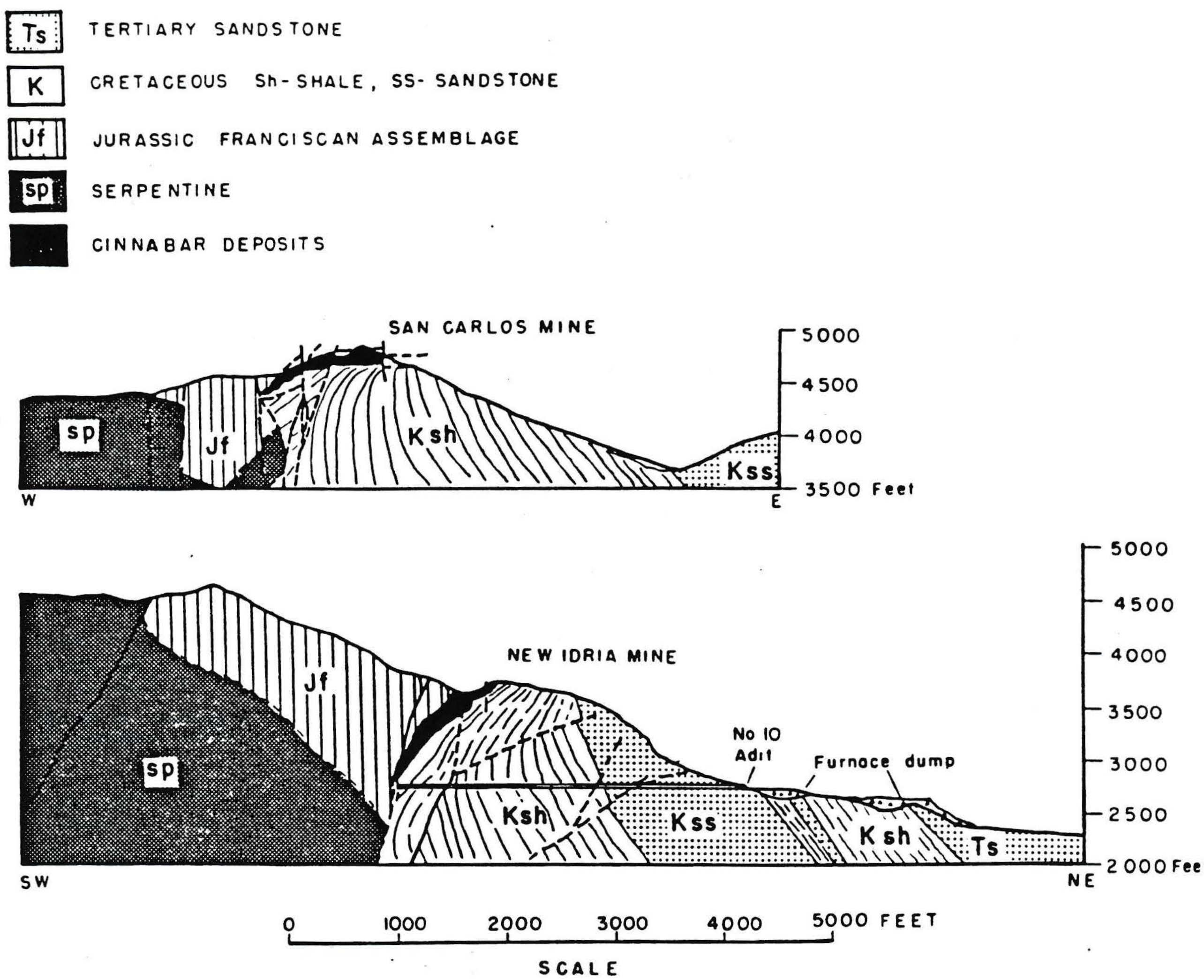


Figure 7. Geologic cross sections through the New Idria and San Carlos mines. The San Carlos mine is field trip stop number 9 as shown on Figure 2.

and serpentine are thrust over Panoche shale and sandstone. Overturning of the Cretaceous sediments and numerous tear faults provided structurally weakened zones for deposition of the mercury-bearing fluids (Fig. 7). Cinnabar is the main ore mineral accompanied by pyrite and marcasite. The cinnabar forms veinlets as grains, films, and crystallized aggregates. Spectacular globular masses of cinnabar up to an inch across were referred to as strawberry ore. Where the ore forms in the serpentine the cinnabar is intertgrown as lenses within silica carbonate rocks. Metacinnabar and native mercury have been reported in the district as minor constituents. A detailed study of the ore mineralogy has never been published.

Stop 9

New Idria is now a ghost mining town but most of the mercury smelter equipment is intact (Fig. 2). The ore was crushed and passed through a rotary kiln at 600°C and the mercury vapors sent through a condenser. The capacity of the plant was 400 tons per day with a production of up to 10,000 flasks per year. The lowering of mercury prices and the stricter regulations on waste disposal forced the company to close in 1972. A short time will be spent inspecting the mill.

Stop 10

The San Carlos open pit deposit was discovered in 1858 and has produced in excess of 60,000 flasks of mercury (Fig. 7). Most of the ore was taken from an open cast pit some 600 feet long, 300 feet wide, and at least 100 feet deep. The cinnabar was deposited in fractured, argillized, and indurated sandstone and shale of the Panoche formation. The main ore body contained fracturers filled with cockscomb quartz crystals with interstitial cinnabar and cinnabar cements in the fractured parts. In this mineralized zone NW trending tear faults have offset the earlier formed New Idria thrust and produced a highly fractured zone that hosted the mercury mineralizing solutions (Eckel and Myers, 1946) The San Carlos open pit can be reached from the mine road at the Clear Creek-Spainish Lake-Idria road junction. The road is private with a locked gate and permission is required to enter.

NEW IDRIA-PANOCHE PASS

The New Idria mine road follows the San Carlos Creek Canyon where a nearly complete sequence of the Tertiary marine sediments can be seen deposited above the Morena Formation of Upper Createceous age (Fig. 2 & 8). All of these rocks dip steeply northeastward as part of the south limb of the Vallecitos synform. The New Idria road then follows the northwestern trending axis of the Vallecitos synform and then turns northward through the Griswald Creek Canyon where the northeast limb of the Vallicetos synform exposes the Tertiary section down to the Upper

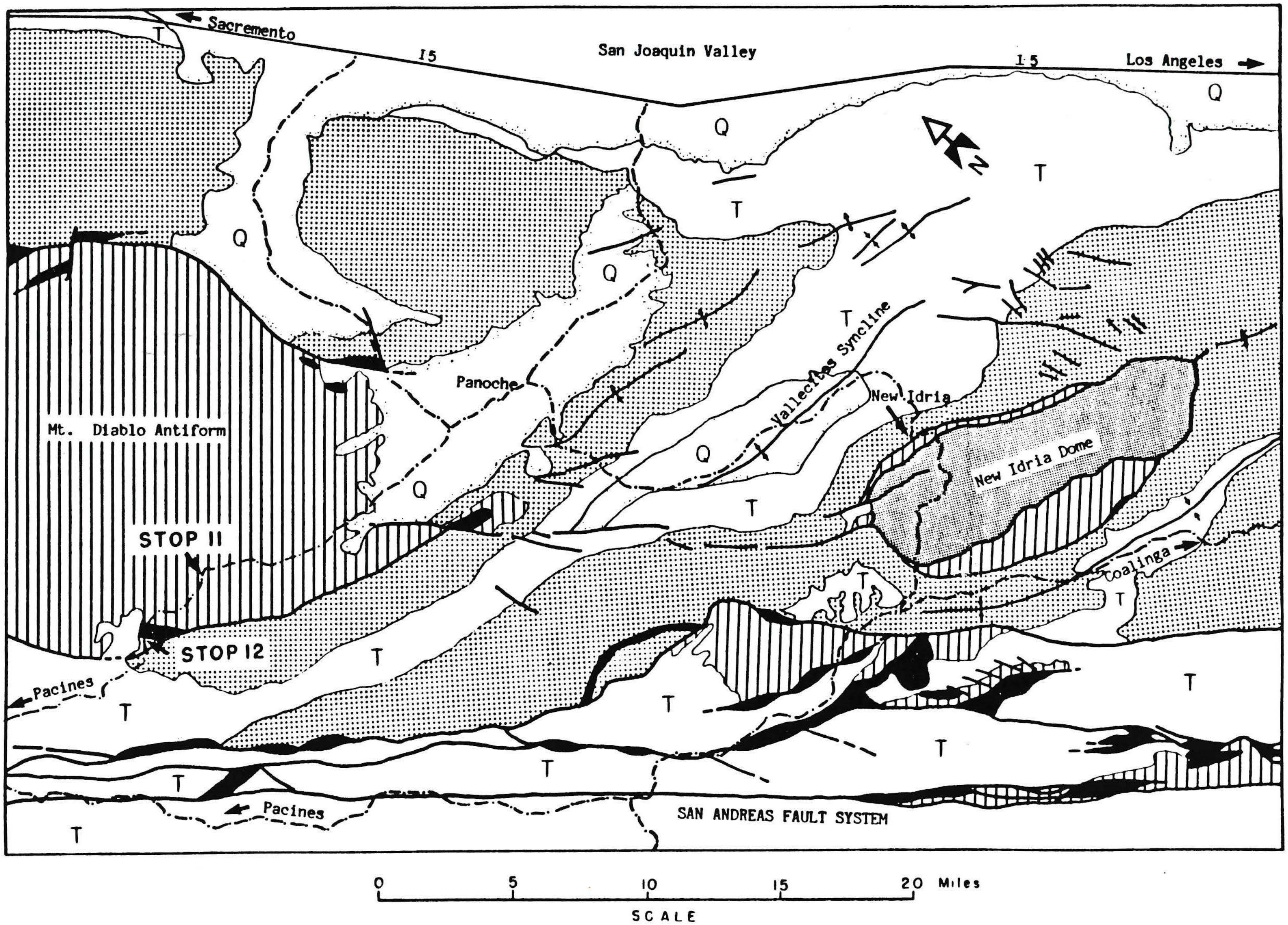


Figure 8. Geologic sketch map of Diablo Range between New Idria dome and the Mt. Diablo antiform. Field trip stops 11 and 12 are shown as well as the main roads of the area. Map simplified after Jennings and Strand (1958) and Dibblee (1979). Q- Quaternary, valley deposits, T- Tertiary marine sediments, dots - Cretaceous marine sedimentary rocks, verical line - Late Mesozoic Franciscan sediments and volcanics, black and fine dots of the New Idria dome - sheared serpentine.

Cretaceous Panoche formation. The junction of the New Idria mines road with the Panoche Pass road is 15 miles from New Idria. Turn left at the junction and follow State Highway J-1 west to Panoche Pass. The Panoche pass road traverses the southern part of the Franciscan core of the Central Diablo Range. These rocks are predominately graywacke of Late Jurassic age with interbedded shales, cherts, and mafic pillow lavas. Minor conglomerate lenses consisting of cobbles and pebbles of chert, mafic volcanic rocks and granite-diorite are present in the southern part of the range. Radiolarian from the interlayered cherts are Tithonian in age (Echeverria, 1978). Low K and Ti tholeiitic magmas formed gabbro sills in the Franciscan graywackes at Ortigalita Peak 95 m.y. ago (U/Pb dating on zircons from granophyres, Mattinson and Echeverria,1980) The Franciscan assemblage is thought to have formed in an accretionary wedge along the margin of North America from Late Jurassic to Late Cretaceous.

High P/T metamorphism is commonly developed within the Franciscan assemblage and consists of two types; (1) In situ regional metamorphism of the Franciscan assemblage. (2) Tectonic blocks of gneissic blueschist and eclogite. In the Central Diablo Range widespread occurrence of jadeitized metagraywackes are found and the age of this metamorphism has been determined to be 92 m.y.(U/Pb dating on metamorphic sphene , Mattinson and Echeverria, 1980). The tectonic blocks are distributed throughout the Franciscan in a random fashion but most often seem to be associated with melanges having a serpentine or shale matrix.

Stop 11

Jadeitized graywacke is exposed along the Panoche Pass Road 19.1 miles west of the junction with the New Idria mine road(Fig. 8). These rocks contain radial sprays of jadeitic pyroxene sometimes intergrown with lawsonite or glaucophane. The original clastic texture of the rock is retained and detrital grains of quartz, feldspar, and lithic fragments are set in a pasty matrix consisting of chlorite, mica, and stilpnomelane. These jadeite-bearing graywackes grade into metagraywackes where no jadeite is present. The critical assemblages for the metagraywackes are:

quartz-jadeitic pyroxene-lawsonite + aragonite
quartz-lawsonite-albite + pumpellyite + aragonite

Other minerals present are glaucophane, chlorite, sphene, phengite, stilpnomelane. In some areas, a progressive metamorphism can be mapped but in the Central Diablo Range isograds have not been successfully established because of the post-metamorphic deformation and poor exposures. Ernst (1965) in his study of this area has demonstrated the progressive nature of the metamorphism in the Panoche Pass area but was unable to establish isograds. The composition of the jadeite in these graywackes is impure and contains up to 20-30% acmite-diopside. This is in contrast to the pure jadeite veins in the albite-crossite schist of the Clear Creek jadeite locality. Veins cutting the jadeite-bearing graywackes at Panoche Pass contain albite+quartz with some aragonite.

Stop 12

Tectonic blueschist blocks associated within serpentine melange occur along the Tres Pinos Creek near the Jones Ranch 3.1 miles west of Stop 11. This is private property and permission to enter is required from Robert E. Jones, the owner. A traverse up the Tres Pinos stream bottom above the Jones Ranch reveals a typical assortment of blueschist tectonic blocks. These blocks are considered to have been enclosed and transported within a serpentine melange east of the Bradford fault near the Jones Ranch. According to Ernst (1965) the blocks are coarse grained gneissic amphibolite and glaucophane schists. Hornblende-plagioclase-garnet-epidote-apatite-sphene-rutile are common in the amphibolites which are partly converted to blueschist assemblages consisting of crossite-lawsonite-chlorite-sphene-apatite. Rare occurrences of eclogite (garnet-omphacite-rutile) can be found but many of these blocks have retrograded to chlorite-glaucophane-lawsonite-phengite. These tectonic blocks give radiometric ages of 150-160 m.y. and are found throughout the Diablo Range. Moore (1984) has suggested that these blocks have been derived from a Pre-Franciscan metamorphic terrain. Post-metamorphic tectonic movements introduced these blocks into the active subduction trench during Franciscan time and overprinted them with a later lower grade blueschist assemblage. Reaction rinds of actinolite and chlorite on the outer surfaces of the tectonic blocks records metasomatism between the blocks and the enclosing serpentine.

Associated with the gneissic tectonic blocks are mafic glaucophane schist that have distinctive pale bluish color. These are in-situ Diablo Range metabasalts that have been eroded and mixed with the tectonic blocks. Mineral assemblages for these rocks are crossite-lawsonite-chlorite-sphene accompanied by minor amounts of phengite, stilpnomelane, aragonite, acmite, albite, pyrite.

The field trip ends at Stop 11. Return to Pacines west along the Panoche Pass road approximately 12.1 miles from the Jones Ranch. At Pacines, take State Highway 25 north to its junction with U.S. Highway 101 (25.5 miles). From this junction it takes approximately 1 to 1.5 hours to drive to Stanford University.

TABLE 3. MINERALS OF THE NEW IDRIA DISTRICT

ULTRAMAFIC ROCKS

| Primary (peridotite) | Secondary (serpentine) |
|---|---|
| Olivine | Chrysotile |
| Orthopyroxene | Antigorite |
| Clinopyroxene | Lizardite |
| Chromite | Brucite |
| | Magnetite |
| | Talc |
| | Josephinite |

Weathering minerals in the sheared serpentine.

| | |
|---|---|
| Artinite | Annabergite |
| Calcite | Aragonite |
| Coalingite | Desautelsite |
| Dolomite | Dypingite |
| Hydromagnesite | Magnesite |
| Pyroaurite | Reevesite |

METASOMATIZED ULTRAMAFIC ROCKS

| | |
|---|---|
| Chlorite | Kammererite |
| Clinochlore | Penninite |
| Diopside | Andradite |
| Melanite (Ti-andradite) | Grossularite |
| Magnetite | Ilmenite |
| Perovskite | Rutile |
| Vesuvianite (Ce-rich in places) | Titanite |
| Chevkinite | Uvarovite |
| Dolomite | Calcite |
| Apatite | |

| METAMORPHIC MINERALS IN TECTONIC INCLUSIONS | |
|---|---|
| Acmite | Actinolite |
| Albite | Analcite |
| Apatite | Calcite |
| Chlorite | Clinozoisite |
| Crossite | Epidote |
| Garnet (Spessartite) | Glaucophane |
| Hydrogarnet | Jadeite |
| Lawsonite | Muscovite |
| Natrolite | Prehnite |
| Pumpellyite | Pyrite |
| Quartz | Stilpnomelane |
| Thomsonite | Zoisite |

| MINERALS IN THE SYENITE AND CAMPTONITE | |
|---|---|
| Acmite | Analcite |
| Aegirine-augite | Apatite |
| Calcite | Chalcocite |
| Chlorite | Cinnibar |
| Clinozoisite | Crossite |
| Galena | Magnetite |
| Muscovite | Natrolite |
| Olivine | Pyroxene |
| Plagioclase ($An_5$ to $An_{89}$) | Prehnite |
| Pyrite | Richterite (barkevikite) |
| Spessartite | Titanite |

| HYDROTHERMAL VEIN MINERALS IN TECTONIC INCLUSIONS | |
|---|---|
| Albite | Analcime |
| Anilite | Apatite |
| Fluorapatite | Strontium-apatite |
| Banalsite | Baotite |
| Bario-orthojoaquinite | Benitoite |
| Brochantite | Chalcocite |
| Native copper | Covellite |
| Datolite | Digenite |
| Djurleite | Fresnoite |
| Native gold | Gypsum |
| Joaquinite | Jonesite |
| Malachite | Natrolite |
| Neptunite | Adularia |
| Parawollastonite | Pectolite |
| Serandite | Stevensite |
| Stilpnomelane | Strontiojoaquinite |
| Taramellite | Thompsonite |
| Zircon | |

| MINERALS FROM THE NEW IDRIA MERCURY MINES | |
|---|---|
| Calomel | Cinnabar |
| Eglestonite | Metacinnabar |
| Montroydite | Quartz |
| Stibnite | |

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