DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF– 791
ROSS–DISTRIBUTION OF METAMORPHIC ROCKS AND MINERAL OCCURRENCES, SANTA LUCIA RANGE, CALIF.

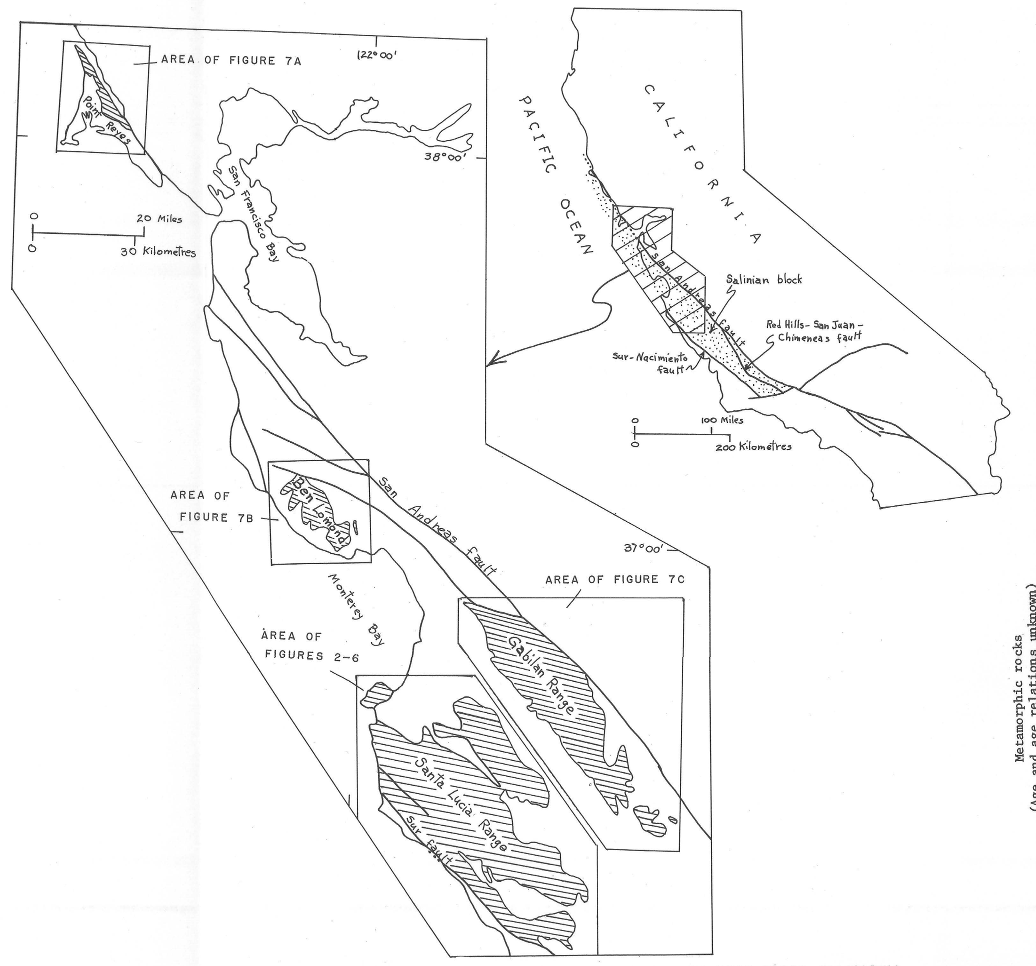

FIGURE 1. INDEX TO AREAS OF BASEMENT ROCK IN THE CENTRAL SALINIAN BLOCK, CALIFORNIA THAT CONTAIN METAMORPHIC ROCKS.

EXPLANATION FOR GEOLOGIC MAP

FIGURES 2–6

Cretaceous and younger sedimentary rocks and alluvium

Mesozoic granitic rocks

Metamorphic rocks (Age and age relations unknown)

- Quartzofeldspathic rocks — Dominantly gneiss, granofels, and impure quartzite; lesser schist, amphibolite, and calcareous rocks
- Coast Ridge belt — Characterized by abundant marble and hornfels and granofels that appear to be less well banded than the quartzofeldspathic rocks to the east
- Schist of Sierra de Salinas — Monotonous biotite quartzofeldspathic schist that is probably metagraywacke
- Graphitic and pyritic belt (Los Padres unit of Wiebe, 1970) — Distinctive red-weathering quartzite, calc-hornfels, and granofels with locally abundant black shiny graphite flakes
- Pelitic schist belt — Biotite-rich schist layers are relatively abundant, but distinction from quartzofeldspathic rocks rather arbitrary

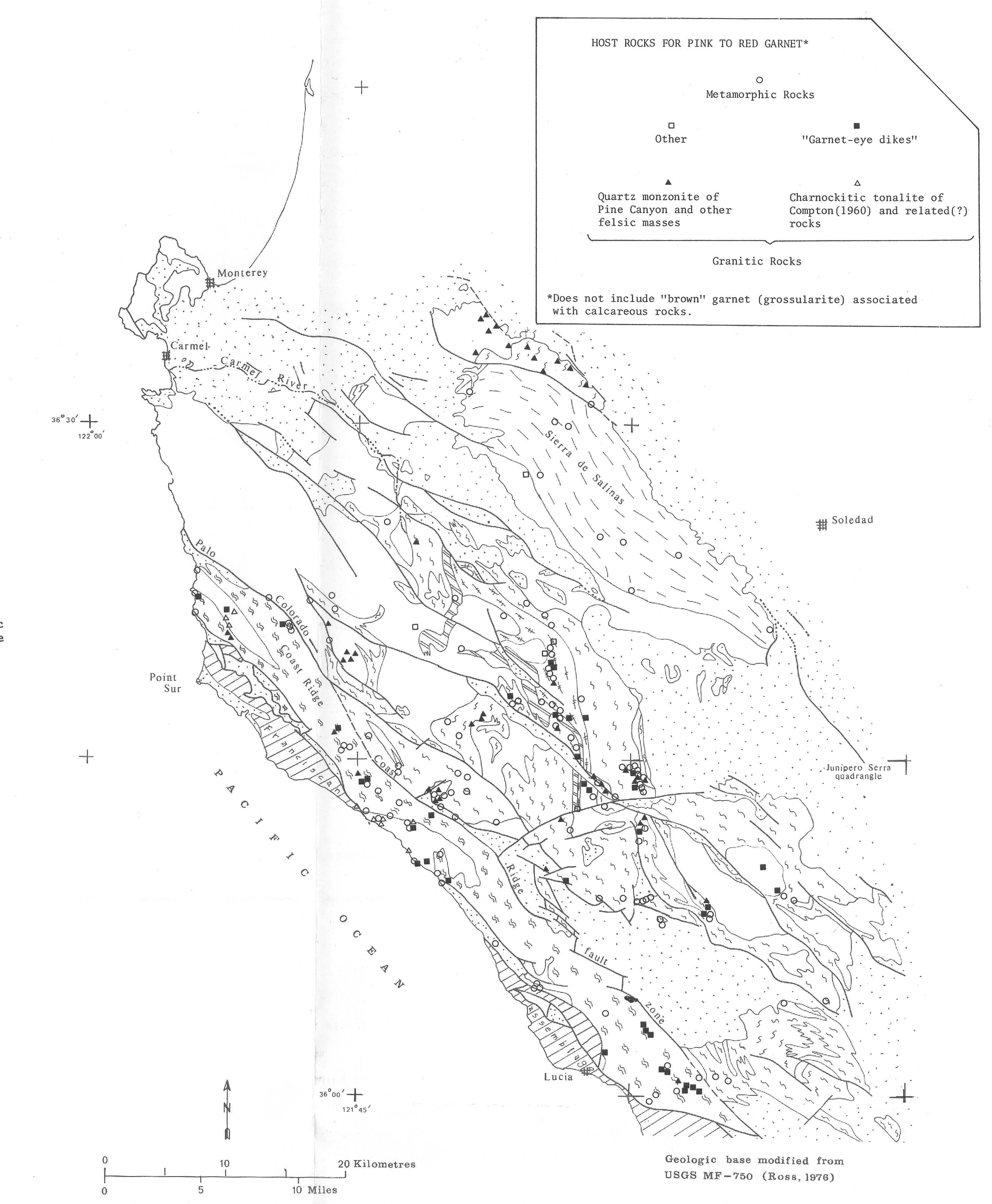

FIGURE 2. PINK TO RED GARNET

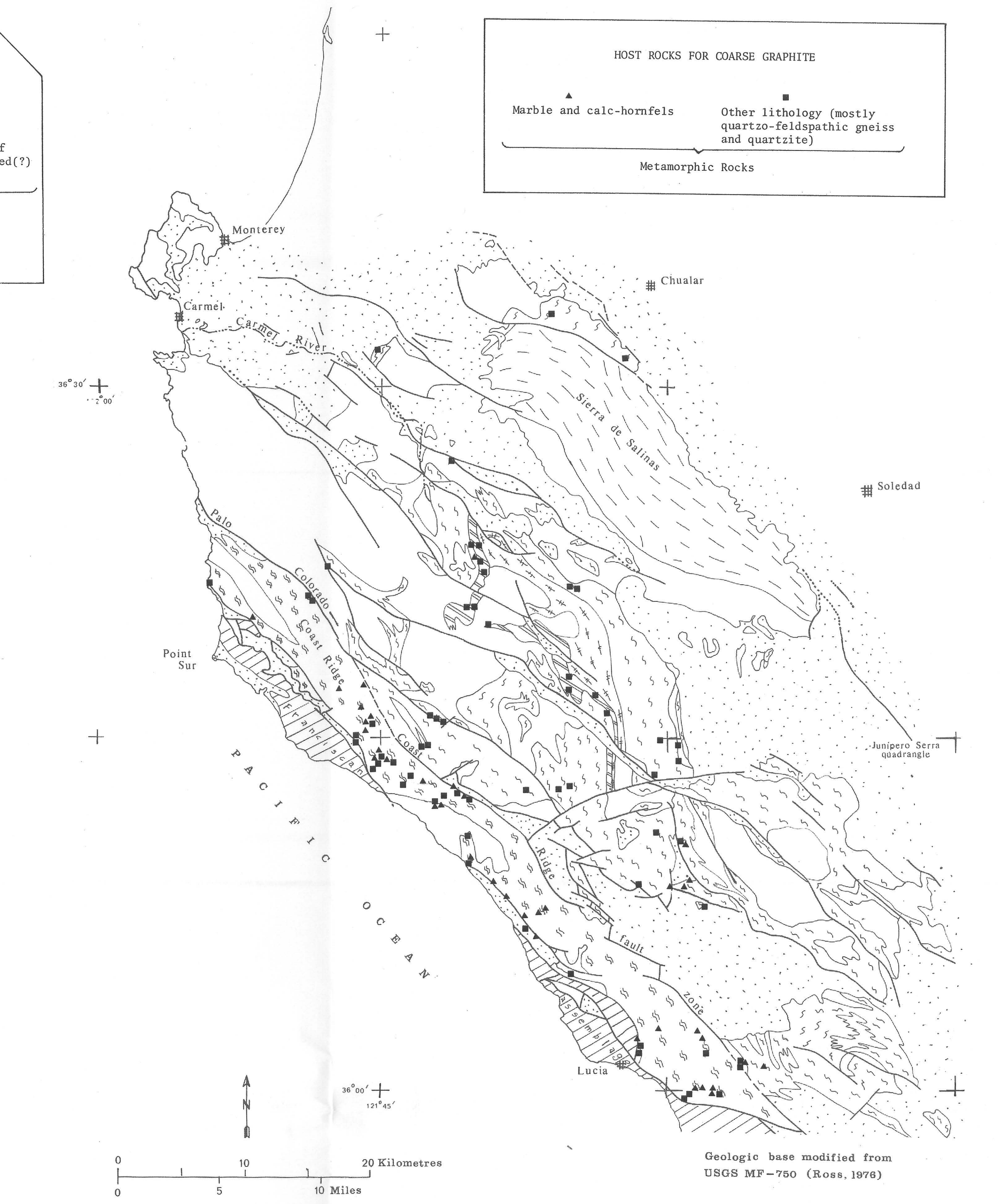

FIGURE 3. COARSE GRAPHITE

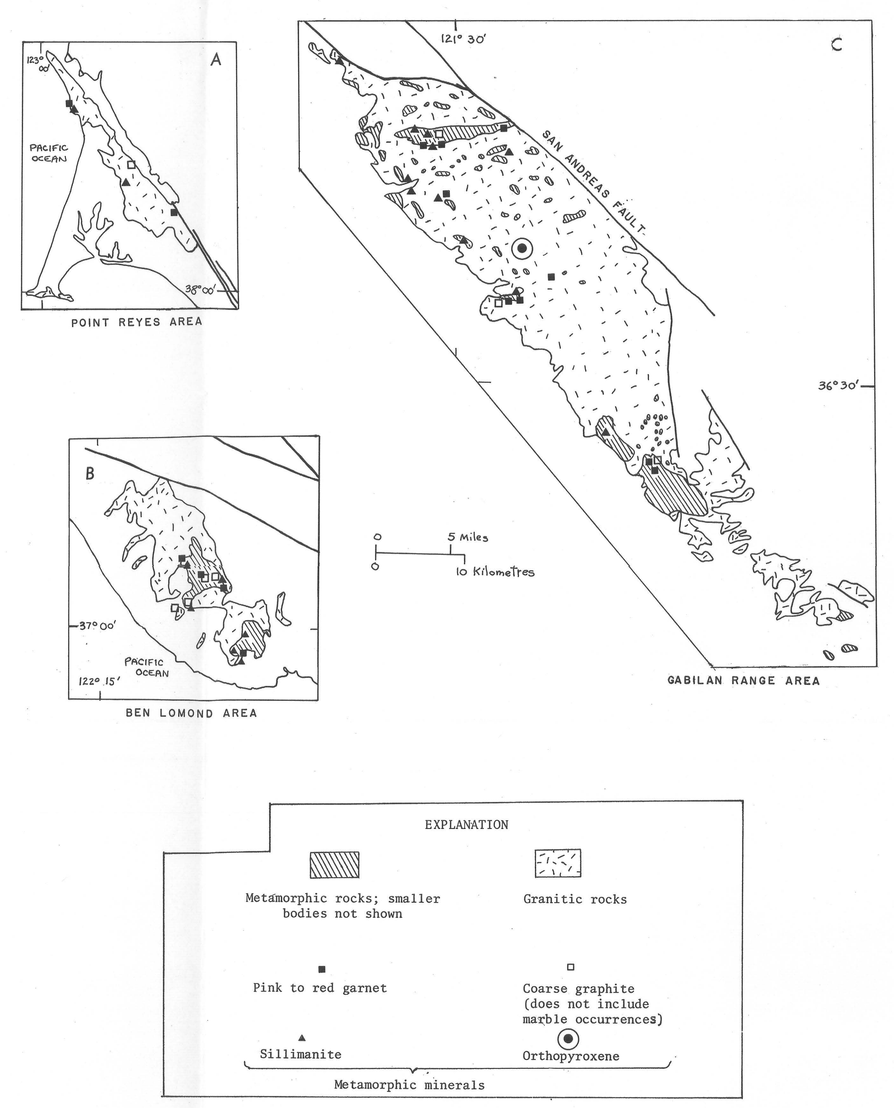

FIGURE 7. MAPS SHOWING DISTRIBUTION OF SELECTED METAMORPHIC MINERALS FROM POINT REYES, BEN LOMOND, AND GABILAN RANGE AREAS.

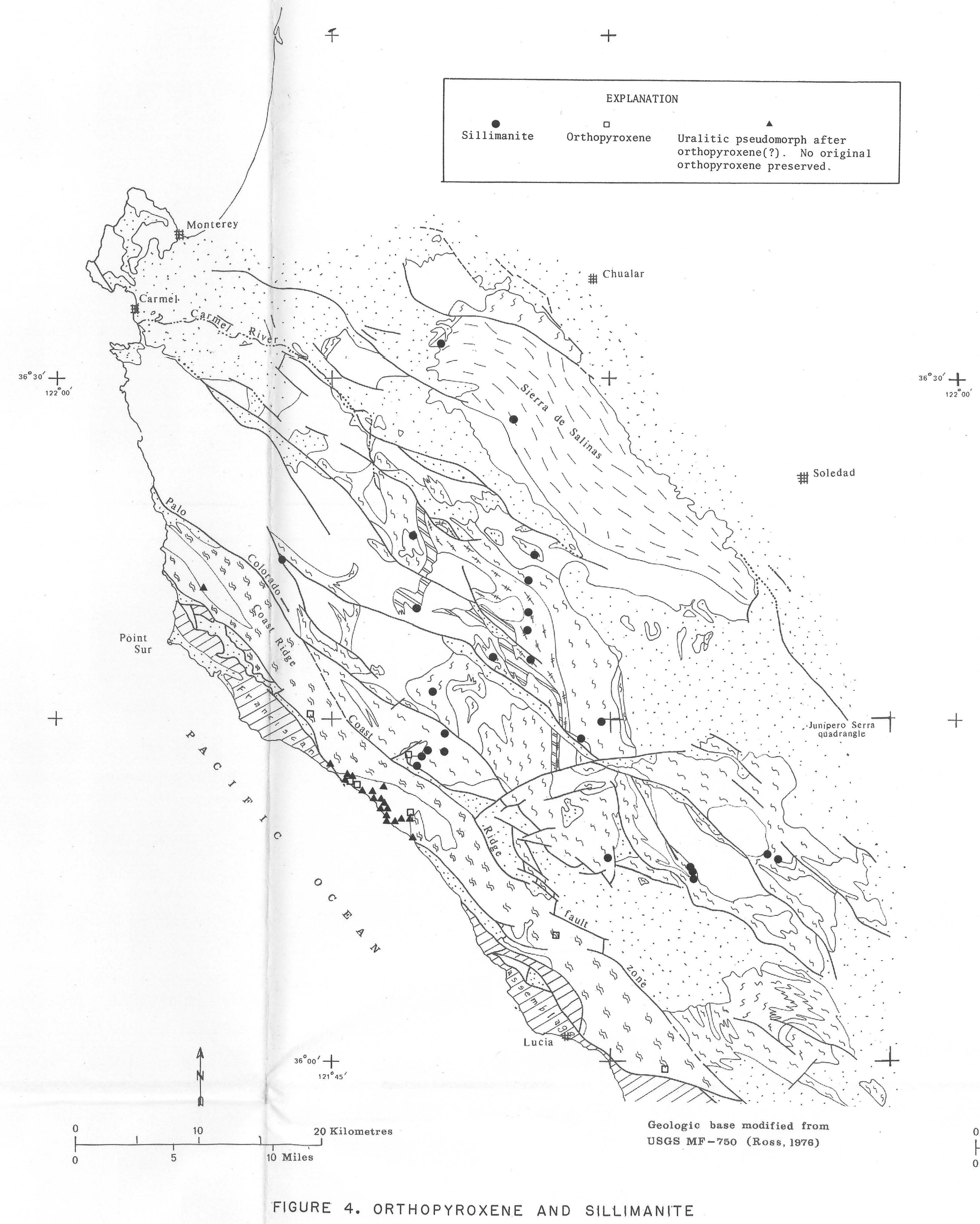

FIGURE 4. ORTHOPYROXENE AND SILLIMANITE

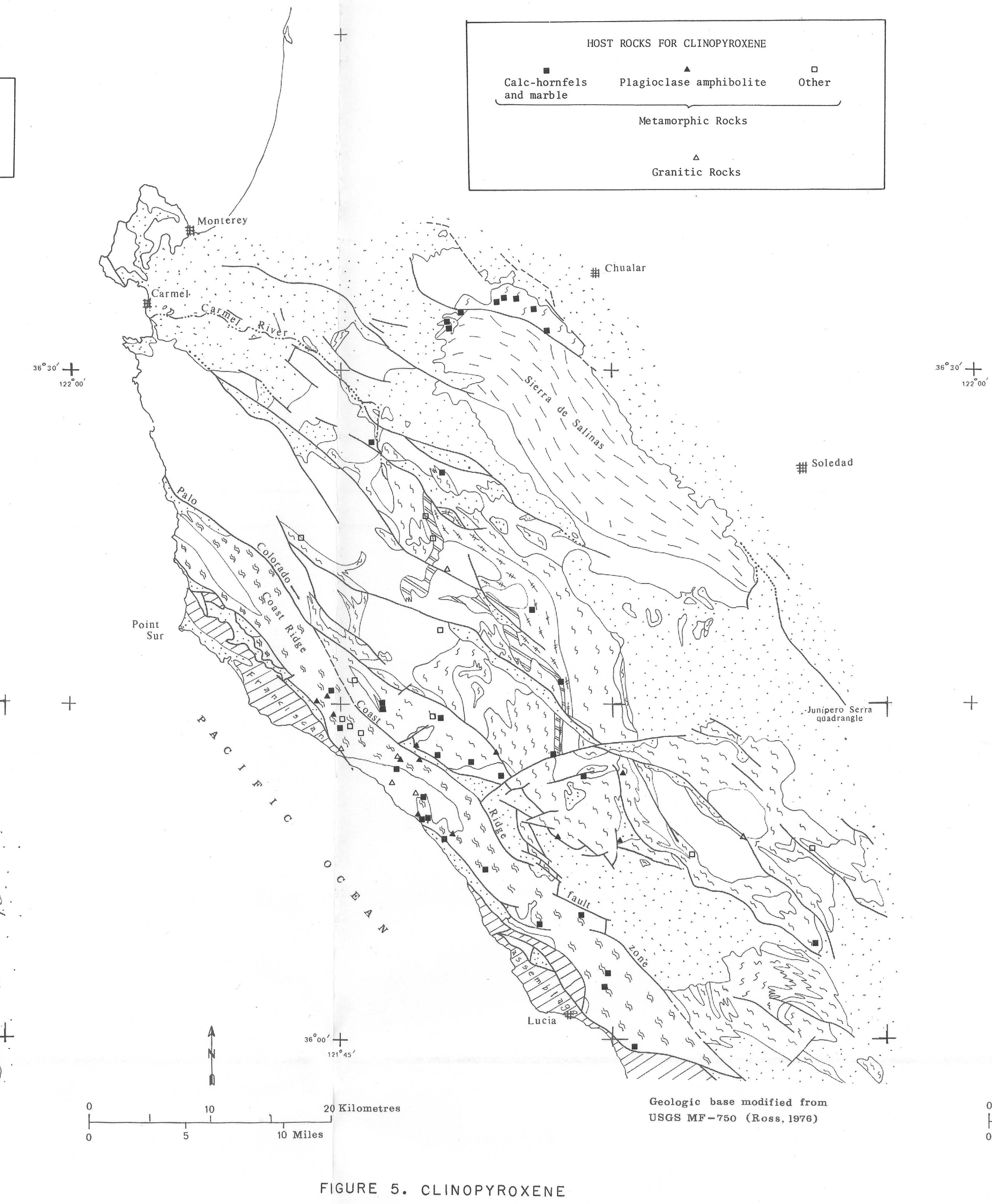

FIGURE 5. CLINOPYROXENE

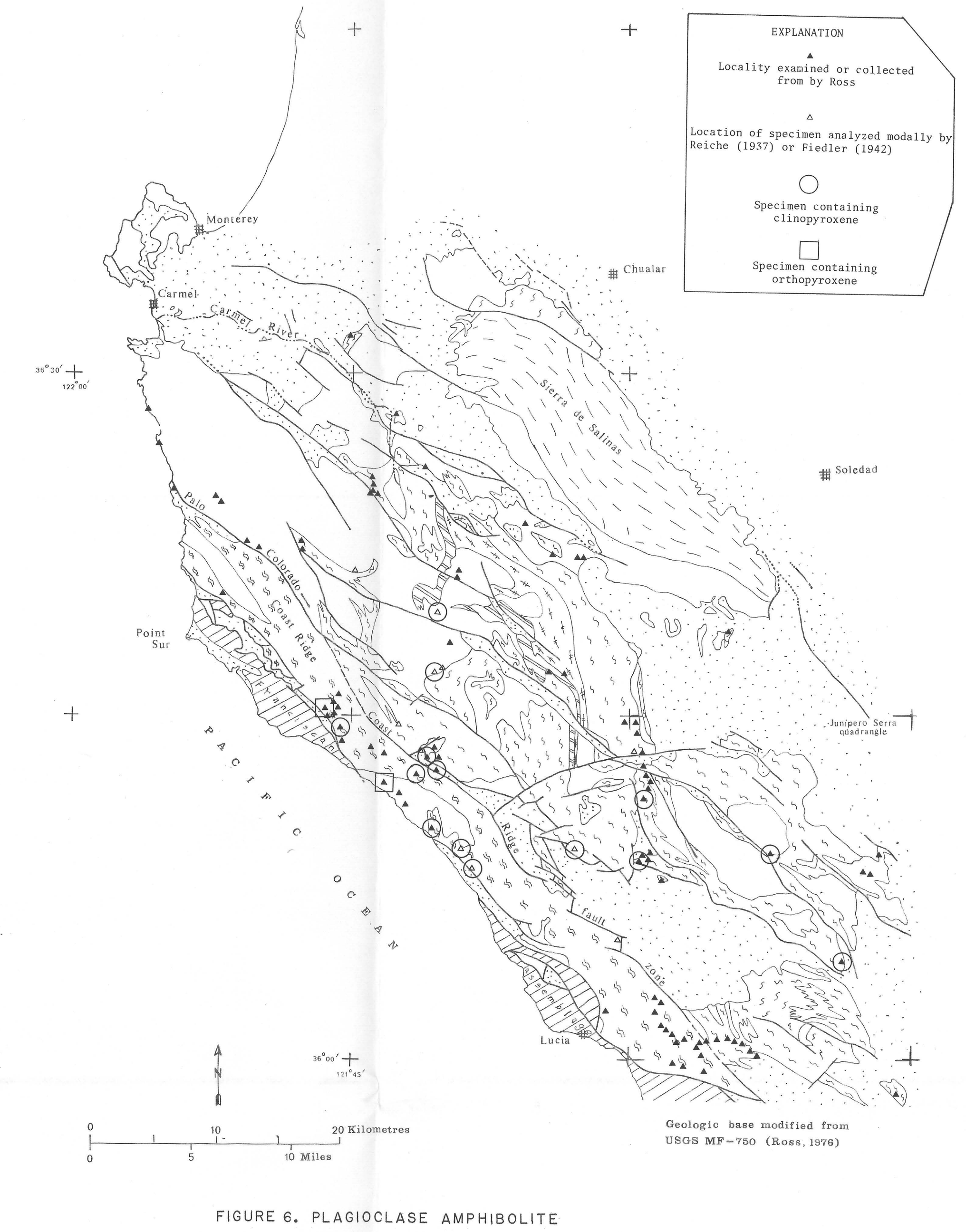

FIGURE 6. PLAGIOCLASE AMPHIBOLITE

FIGURES 2–6. MAPS SHOWING DISTRIBUTION OF SELECTED METAMORPHIC MINERALS AND ROCKS, SANTA LUCIA RANGE, CALIF.

INTRODUCTION

The metamorphic terrane of the Santa Lucia Range has been tentatively divided into seven belts that may have stratigraphic significance (Ross, 1976). This terrane is also characterized by the widespread occurrence of certain metamorphic minerals, particularly pink to red garnet and coarse graphite, that characterize the entire terrane, not just specific formations or belts. Other minerals such as sillimanite, orthopyroxene, and clinopyroxene are somewhat more restricted in occurrence but are widely abundant. In addition, plagioclase amphibolite is widely distributed throughout the metamorphic area but is more common in the marble-rich Coast Ridge belt.

It is hoped that these index minerals can be used for correlating similar basement terranes and relating clasts and heavy-mineral suites of Cenozoic sedimentary deposits to this source area. For example, Hutton (1959, p. 10) noted that pink garnet makes up nearly half of the heavy-mineral concentrate from beach sands along the southern part of Monterey Bay; garnet is less common in beach sands to the north. This concentration is predictable from the widespread abundance of garnet in basement rocks in the Santa Lucia Range. Simpson (1972, p. 43) also noted abundant garnet in the heavy-mineral concentrates from Carmel Beach and the mouth of Carmel River, which he thought might be from "contact metamorphism caused by the local lava flows found under the bay." He did note that garnet-bearing metamorphic rocks in Carmel River probably "provide a portion of the garnet." The distribution of garnet in the Santa Lucia Range shown on figure 2 indicates that probably all the garnet was derived from the basement rocks. The mineral index maps may provide similar clues to the less obvious sources of other sedimentary deposits.

MAPS SHOWING OCCURRENCES OF METAMORPHIC INDEX MINERALS

Pink to red garnet (fig. 2)

The most widespread and abundant metamorphic index mineral is pink to red garnet. It is commonly associated with sillimanite in gneiss, granofels, and schist, but it appears to be much more widespread than sillimanite. In addition, some of the felsic granitic rocks have abundant accessory garnet. The so-called "garnet-eye dikes" are in part cross-cutting tabular bodies that contain abundant garnet as rounded crystals as large as 1 or 2 cm, and they are probably related to the garnet-bearing felsic granitic masses. However, similar-looking rocks occur as "sills" or definite layers in the metamorphic section, most commonly near the south end of the Coast Ridge belt. Therefore some of the "garnet-eye dikes" may be mobilized metamorphic layers. The granodiorite and quartz diorite masses generally do not contain garnet, but the charnockitic tonalite and related(?) rocks within the Coast Ridge belt contain impressive, almost "pegmatitic", local concentrations of garnet.

These pink to red garnets are most probably in the compositional range spessartite-almandine (Hutton, 1959, p. 18), but I have made no optical studies of their properties. Tan to reddish brown grossularite-andradite garnets, which are locally abundant in the marble and calc-hornfels, are not included in this compilation.

Coarse graphite (fig. 3)

Graphite in shiny black flakes is probably the most striking index mineral, next to garnet, in the metamorphic terrane. Reiche (1937) noted graphitic quartzite in the Coast Ridge belt, and Wiebe (1970) delineated a stratigraphic unit in the central part of the range, largely on the basis of abundant graphite. Graphite is most common in those two areas but also is widely scattered throughout the rest of the range. The material called graphite here is not the black, nondescript, dense, organic material that is commonly and probably erroneously reported as graphite,[1/] but rather is shiny silvery-black flakes as large as 1-2 mm across. Although such flakes are relatively common in marble, their abundance in gneiss, granofels, and quartzite, particularly as widely and abundantly distributed as in the Coast Ridge belt, seems to be unusual and very possibly of stratigraphic value.

Orthopyroxene and sillimanite (fig. 4)

Orthopyroxene and sillimanite are plotted on the same map for convenience, but they occur almost mutually exclusive of each other. With one exception, all the orthopyroxene occurs west of the Palo Colorado-Coast Ridge fault zone, and all of the sillimanite occurs east of this zone. In addition, R. R. Compton (oral commun., 1971) noted possibly recrystallized charnockitic tonalite containing garnet and uralitic pseudomorphs after orthopyroxene(?) locally in the Junipero Serra quadrangle. My data are admittedly limited in the Junipero Serra area, but for the range as a whole, they suggest that the Coast Ridge belt, because of either original composition or present metamorphic grade, differs from the rest of the metamorphic terrane.

[1/] Miyashiro (1973) noted that the black carbonaceous matter usually called graphite in the literature is more comparable to semi-anthracite or anthracite and that graphite is only formed when the amphibolite facies is reached (Izawa, 1967).

The orthopyroxene occurs most commonly in the charnockitic tonalite of Compton (1960) but is also found in granofels and gneiss in what probably are rocks of the granulite facies.

The sillimanite occurs in gneiss, granofels, and schist and is commonly associated with pink to red garnet.

Clinopyroxene (fig. 5)

Clinopyroxene is found most commonly in marble and calc-hornfels. It is also common in some plagioclase amphibolite in the Coast Ridge belt and rare in the same rock to the east. Less commonly, clinopyroxene is found in quartzite, granofels, and gneiss. Charnockitic tonalite and some of the gabbroic rocks also contain clinopyroxene. Except for occurrences in carbonate rocks, most of the clinopyroxene is in the southwest part of the metamorphic terrane, which suggests a higher metamorphic grade there relative to the rest of the metamorphic terrane.

Plagioclase amphibolite (fig. 6)

All the field occurrences I have found of dark hornblende-plagioclase rocks of diverse forms and origins are shown on this map. Some are inclusion masses in granitic bodies that are in part schistose, others are layers in the metamorphic section closely associated with marble, and others are possibly igneous masses of unknown shape and relations. Some of the plagioclase amphibolite is definitely metamorphic (interlayered with gneiss, schist, granofels, and marble), some is definitely associated with gabbro and probably is igneous, but most has a problematical origin.

The amphibolite is most abundant in the Coast Ridge belt, where it most commonly contains clinopyroxene and rarely orthopyroxene.

METAMORPHIC ZONES IN THE SANTA LUCIA RANGE AND RELATIONS TO NEARBY METAMORPHIC TERRANES

Compton (1966, p. 283) noted that the metamorphic assemblages of the highest grade of the amphibolite facies and locally of the granulite facies are found in the southwest part of the Santa Lucia Range and that to the northeast the rocks are finer grained and entirely in the amphibolite facies. The mineral index maps of the distribution of coarse graphite, orthopyroxene, and clinopyroxene tend to show a zone of higher grade rocks to the southwest, but it is also possible that these rocks are virtually limited to the Coast Ridge belt and that the apparent zoning is in reality an abrupt change across a zone of structural dislocation. However, assuming that the entire metamorphic terrane of the Santa Lucia Range is relatively coherent, the zones still may not be so marked as Compton (1966) suggested. My field observations suggest similar metamorphic grain size and similar migmatitic mixtures of granitic and metamorphic rocks throughout the Santa Lucia Range. Except for orthopyroxene, the same metamorphic minerals occur throughout the range, although concentrations vary.

Earlier workers attempted to compare the schist of Sierra de Salinas with the other metamorphic rocks. However, the schist is unique in being almost devoid of intrusive granitic rocks, except at its edges (Ross, 1976). Although it appears to be of lower grade than the migmatitic terrane to the west, the schist contains garnet and sillimanite and, near the edges, is coarse grained and even locally migmatitic. North of the schist belt there is abundant migmatitic mixing of metamorphic rock and granitic material. Thus there is little real difference in metamorphic grade, grain size of metamorphic rocks, or amount of migmatitic material within the Santa Lucia Range east of the Coast Ridge belt.

The distribution of medium- to high-grade metamorphic minerals in the Point Reyes, Ben Lomond, and Gabilan Range areas is plotted on figure 7 for comparison with the Santa Lucia terrane. Pink to red garnet, sillimanite, and coarse graphite are fairly widespread in all these terranes, and one possibly significant occurrence of orthopyroxene in metamorphic rock is recorded in the Gabilan Range. Aside from marble, most of the metamorphic rocks in these three terranes are schist, but locally all three contain gneiss with some migmatite.

These data suggest that all the metamorphic rocks in the central part of the Salinian block west of the Red Hills-San Juan-Chimeneas fault (Ross, 1972) are in the amphibolite facies, and where the original compositions are suitable, are characterized by red garnet, sillimanite, and coarse graphite The granulitic and charnockitic rocks appear to represent very special and very localized hot or dry spots in the metamorphic terrane.

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MAPS SHOWING DISTRIBUTION OF METAMORPHIC ROCKS AND OCCURRENCES OF GARNET, COARSE GRAPHITE, SILLIMANITE, ORTHOPYROXENE, CLINOPYROXENE, AND PLAGIOCLASE AMPHIBOLITE, SANTA LUCIA RANGE, SALINIAN BLOCK, CALIFORNIA

BY
DONALD C. ROSS
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