UNITED STATES DEPARTMENT OF THE INTERIOR

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SELECTED COMMODITY OCCURRENCE MAPS FOR THE OPHIOLITE BELTS OF THE WESTERN UNITED STATES

By Jocelyn A. Peterson

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SELECTED COMMODITY OCCURRENCE MAPS FOR THE OPHIOLITE BELTS OF THE WESTERN UNITED STATES

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INTRODUCTION

This paper was written from a talk presented in Athens, Greece, in October 1980.

Two years ago I was asked by Norman J Page, John Albers, and Bruce Lipin to prepare metallogenetic maps for the Western United States ophiolite belts as part of the metallogenetic map subgroup, UNESCO IGCP Project 39. This paper presents some of the important aspects of these maps so that mineral commodities in Western United States ophiolites may be compared with commodity occurrences in other ophiolite regions. The portion of the United States shaded in figure 1, including parts of California, Oregon, and Nevada, is the area of Irwin's (1979) Ophiolitic Terranes map and is the area to be discussed in this paper. Not included in Irwin's map are small ultramafic bodies in Washington.

METHOD OF PREPARING METALLOGENETIC MAPS

The commodities of interest were platinum, chromite, nickel, copper, manganese, iron and titanium, talc, asbestos, and magnesite. To get information about these commodities I accessed the CRIB files stored on the USGS Amdahl computer.[1] CRIB, an acronym for Computerized Resources Information Bank, is a storage and retrieval system comprised of variable-length records, which was designed for metallic and nonmetallic commodity data. A given record may contain information about mine name(s), location, commodities, deposit description, geology, production and reserves, and references. The first step, then, was to examine CRIB records for my commodities in the specified geographic area to see what data were already available and to obtain unavailable data by library research. The new data were put into the CRIB files and the existing data rearranged into a format that could be easily selected for generating computer-plotted maps. Since the computer could not plot the symbols as specified in the metallogenetic maps subgroup legend that was developed previously, these maps were redrafted by hand using the appropriate symbols.

WESTERN NORTH AMERICAN OPHIOLITES

The following brief discussion, taken from Irwin (1977), refers to the very simplified map modified from Irwin (1977) shown in figure 2. Ophiolites occur in the Sierra Nevada, California Coast Ranges, Klamath Mountains, and near Canyon Mountain. Ophiolitic-type rocks also occur in Nevada. The

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[1]For more information about CRIB, contact: Jerlene Bright, Director, Information Systems Programs, Energy Resources Center, P.O. Box 3030, Norman, Oklahoma, 73070, U.S.A.

Figure 1. Location of the ophiolite belts of the western United States.

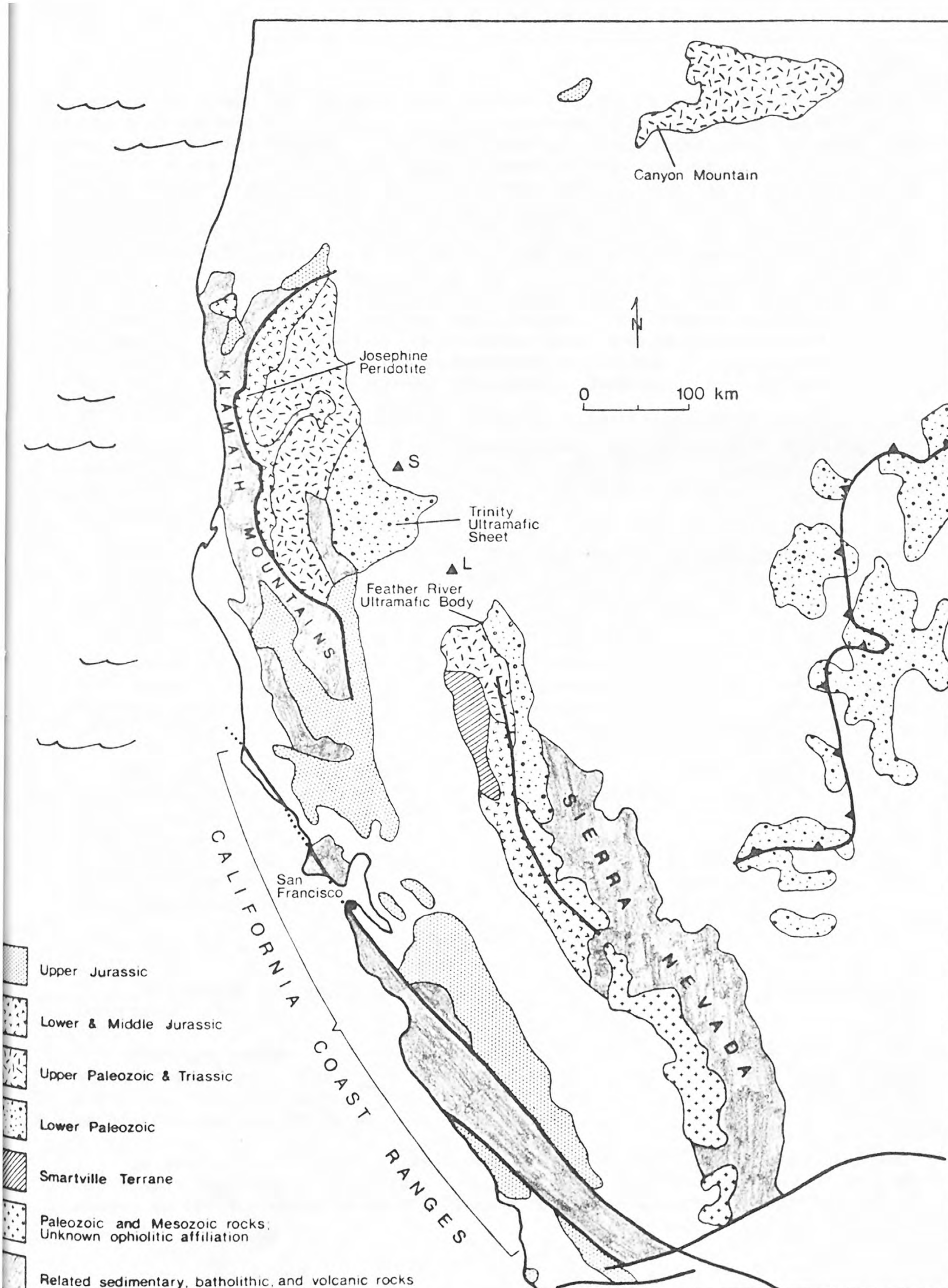

Figure 2. Generalized geology of the ophiolitic terranes of the western United States from Irwin (1977, 1979). Outlines in Nevada, southern Sierra Nevada, and central Oregon represent many small ophiolitic bodies, not large ones.

ophiolites shown in Nevada, the southern Sierra Nevada, and near Canyon Mountain are actually outlines of areas containing ophiolitic bodies too small to show at this scale. The ophiolites are associated with volcanic and oceanic rocks in belts which roughly parallel the present-day coastline and which become progressively younger to the west as evidenced by isotopic and paleontologic ages. The Trinity ultramafic sheet and the Feather River ultramafic body are ophiolites of Lower Paleozoic age. The Trinity sheet is thought to be the base of a tectonically active arc during the Devonian. The Feather River body, northernmost of the Sierra Nevadan Paleozoic ophiolites, is similar to the Trinity ultramafic sheet and has been described as a metamorphosed alpine peridotite and gabbro. Paleozoic sedimentary and volcanic strata occur south of the Feather River body while even further south are isolated patches of ophiolite apparently occurring as pendants or remnant inclusions in the Sierra Nevada batholith. Throughout central Nevada are small Paleozoic serpentine bodies.

In central Oregon, oceanic, continental, and island-arc terranes are exposed through windows in the overlying Cenozoic strata as exemplified by the Canyon Mountain Complex, the largest ophiolite in this area, which is probably a large block in the surrounding melange.

The upper Paleozoic and Triassic belt of the Klamath Mountains consists of melange and slabs of ophiolite and has been divided into several separate ophiolitic assemblages, while in the Sierra Nevada some of the sedimentary assemblages are considered to be of this age.

Lower and Middle Jurassic ophiolites occur on the western edge of the Sierra Nevadas including the Smartville Complex, which may have formed in an interarc basin. Jurassic flysch and volcanic arc deposits occur in the western Klamath Mountains associated with the large Josephine peridotite.

The youngest ophiolites of upper Jurassic age, occur primarily in the California Coast Ranges and are considered to be the basal part of the Great Valley sequence flysch, beneath which the Franciscan assemblage of the Coast Ranges is thrust. Additionally, there are several Upper Jurassic peridotites west of the Josephine peridotite but their relationship with the Coast Ranges ophiolites is uncertain. The northernmost body, however, is related to the Coast Ranges ophiolites.

MAJOR MINES

Only manganese, copper, nickel, and asbestos have been of major economic importance (fig. 3).

Although manganese production on a worldwide basis is small, several mines produced more than 1,000 tons prior to the mid-1900's. For these larger deposits, the manganese occurs as massive beds in Franciscan cherts where carbonate minerals may or may not be present.

Several copper deposits have produced greater than 1 million pounds, with minor gold and silver production, and sometimes lead and zinc occur, but no nickel is found. Deposits in the Klamath Mountains are massive sulfide ores

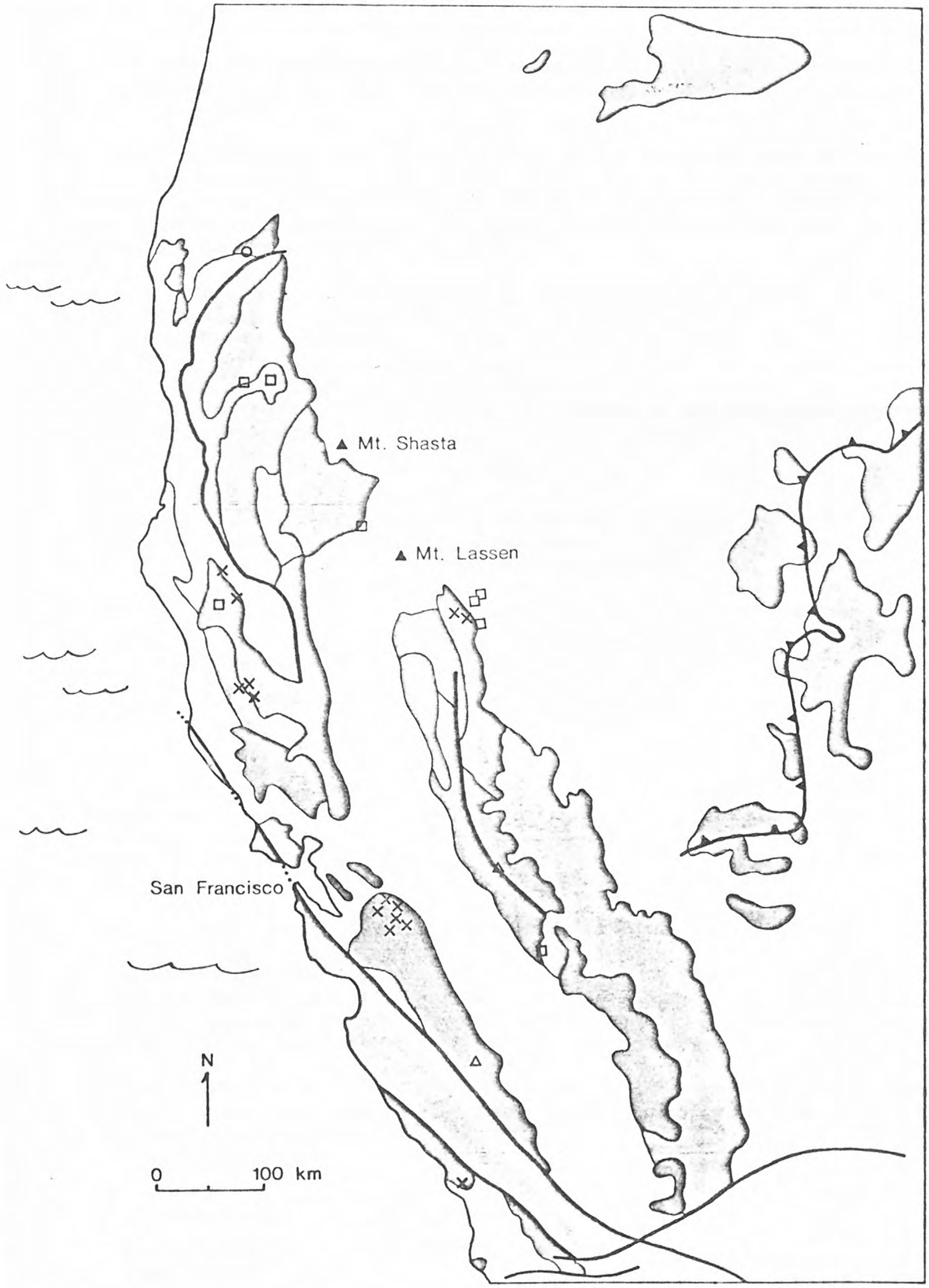

Figure 3. Major deposits; x = manganese, square = copper, triangle = asbestos, and o = nickel.

usually occurring in metasedimentary or metavolcanic schists, whereas the Sierra Nevadan ores are vein types associated with granodiorite or quartz diorite intrusives.

The United States' only nickel mine at Nickel Mountain produces about 26 million pounds annually from Pliocene laterite that is developed on the Upper Jurassic slice of ophiolite in the northern Klamath Mountains. Peridotite and dunite underlie the laterite and the nickel, and possibly cobalt, were derived from olivine in the peridotite and dunite.

Both of the major asbestos-producing areas at Copperoppolis in the Sierra Nevada and Coalinga in the California Coast Ranges produce chrysotile asbestos from serpentinized periodite. In the Copperoppolis area the asbestos is developed as stockworks of cross-fiber veins, whereas the asbestos of the Coalinga area is a mass of matted chrysotile along closely spaced shear planes. The Coalinga deposit is one of the largest in the world with probably 100 million tons of ore.

ASBESTOS

Although asbestos is practically ubiquitous in the serpentinized rocks, figure 4 shows only those deposits where asbestos is important. Productive asbestos deposits are lacking in the Upper Paleozoic-Triassic Ophiolites and in the southern Sierra Nevadas. Most of the deposits contain short-fibered chrysotile asbestos in cross-fiber veinlets. Tremolite predominates in the few nonproductive amphibole asbestos occurrences in the Sierra Nevada and small deposits in central Oregon and near Shasta, but anthophyllite has been found in several places. Producing asbestos deposits are lacking in the Upper Paleozoic-Triassic Ophiolites and in the southern Sierra Nevadas.

TALC

A few talc deposits along the Sierra Nevada and one in the Klamath Mountains have produced minor quantities (fig. 5) but talc, like asbestos, is fairly ubiquitous. The talc, which does not usually occur with carbonate minerals, generally forms irregular bodies in schists or other metamorphic rocks or veinlets in serpentinite.

MAGNESITE

Magnesite deposits are restricted to localities in the southern Sierra Nevada and widely scattered throughout the Coast Ranges (fig. 6). Although most of the magnesite occurs as veins within shears in serpentinites some occurs as large replacement bodies within the serpentinites.

Little information is available about the volcanic association of these nonmetallic commodities except that the Klamath Mountains talc deposit (see fig. 5) is associated with an alaskite porphyry.

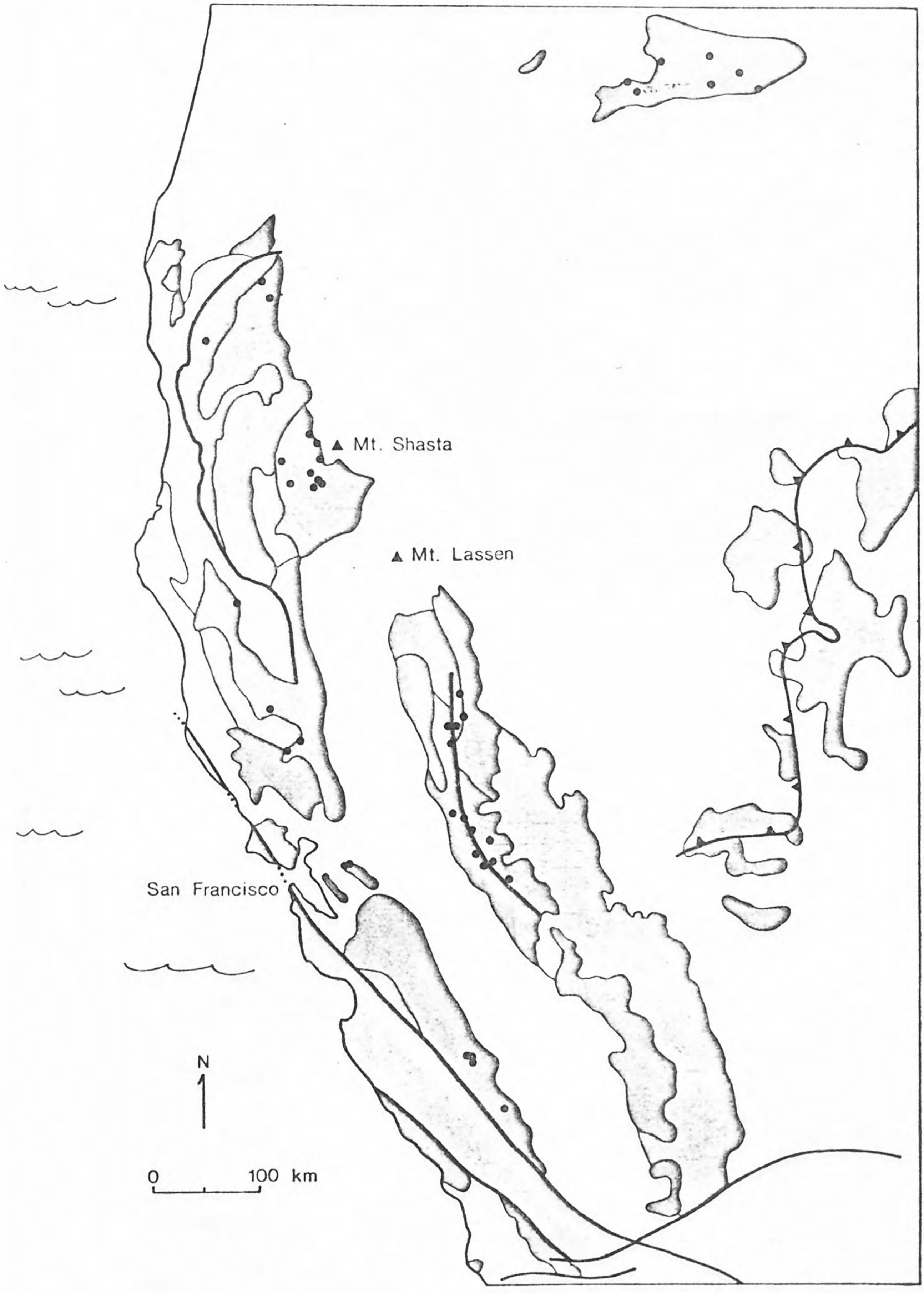

Figure 4. Distribution of asbestos.

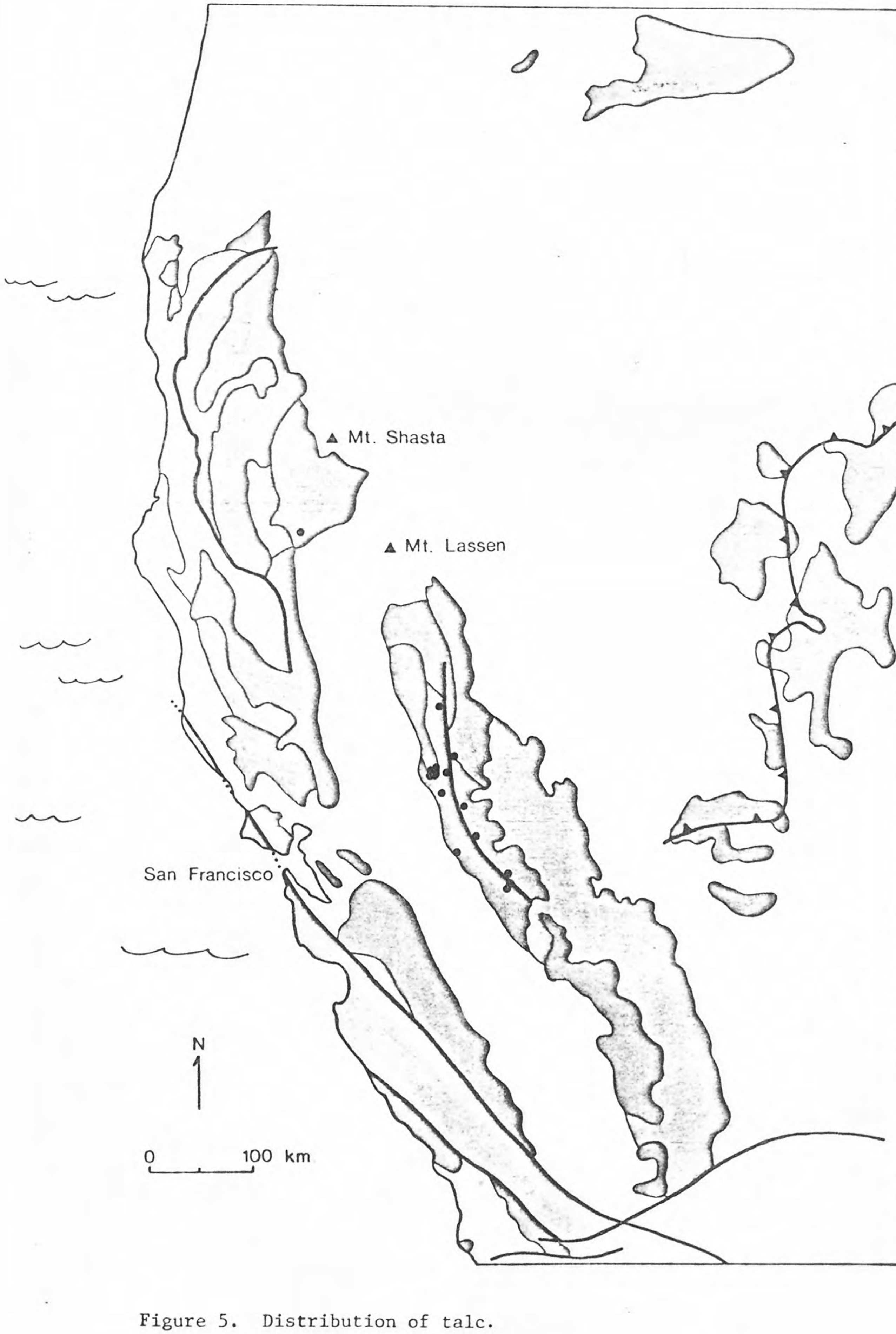

Figure 5. Distribution of talc.

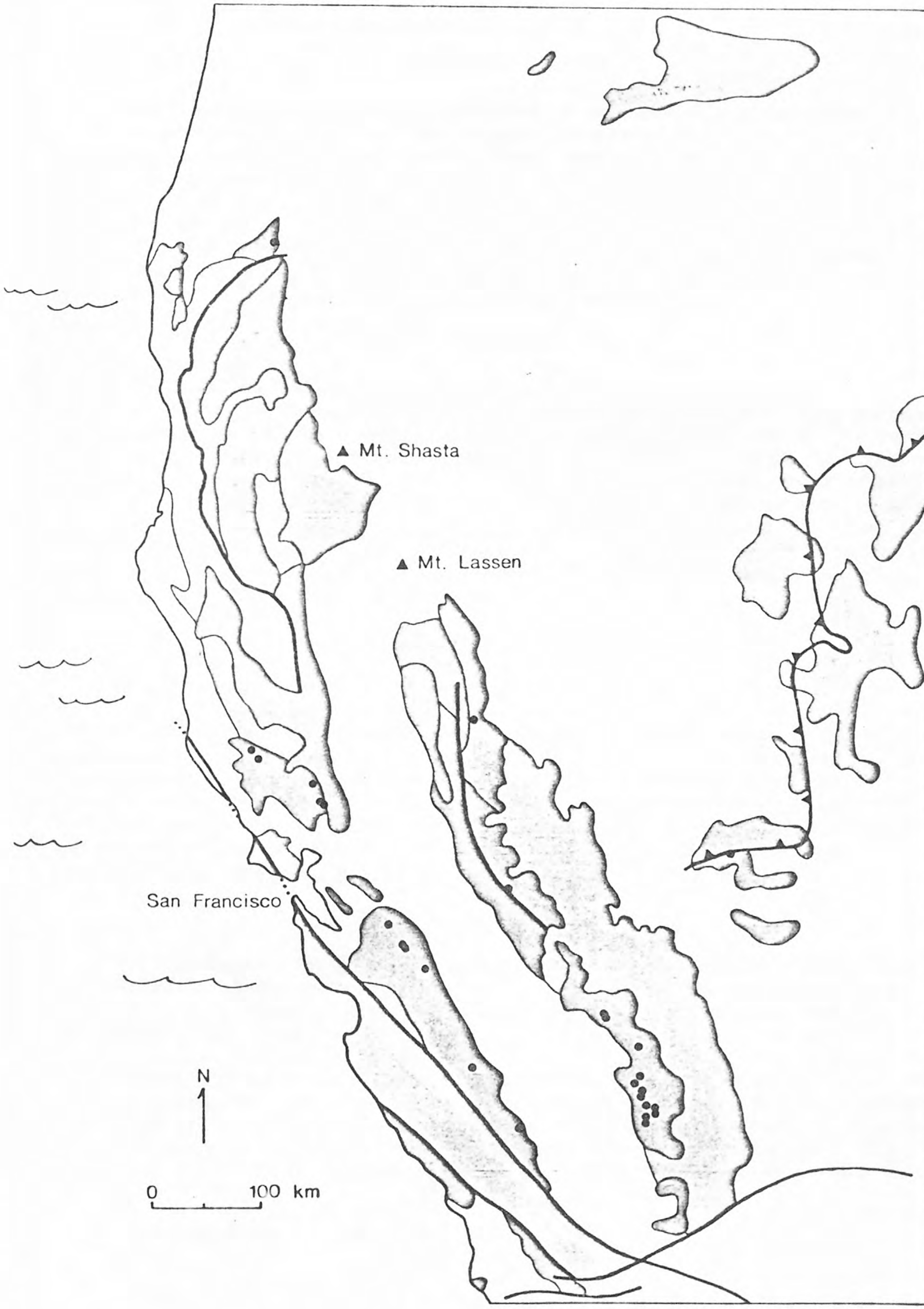

Figure 6. Distribution of magnesite.

IRON AND TITANIUM

Most titanium, occurring as ilmenite or occasionally titanomagnetite, is a minor product in platinum and chromite placers (fig. 7). Titanium, like asbestos, seems to be absent in the Upper Paleozoic-Triassic ophiolite belts while small nonproductive occurrences are common in the older Paleozoic terranes but those deposits that have produced are associated with the Jurassic belts. A few lateritic aluminum deposits in the Klamath Mountains have produced minor amounts of iron from hematite. In those deposits that have produced, iron or titanium is typically the minor product. Little is known about the igneous association of iron and titanium.

MANGANESE

Manganese minerals are usually in pelagic sediments associated with chert (fig. 8) but a few deposits in the Sierra Nevada are associated with volcanics and elsewhere a few are associated with massive chert. In the Sierra Nevada, most sediments have been metamorphosed to quartzites and schists. The most important manganese deposits occur in the California Coast Ranges where the host rock is the Franciscan Formation. The Klamath Mountains are relatively lacking in manganese although there are some occurrences in the Upper Paleozoic-Triassic ophiolite. Manganese oxides such as psilomelane and pyrolusite and the manganese carbonate, rhodochrosite, are the major ore minerals with about 40 percent of the deposits containing carbonate ore.

COPPER

Copper occurrences are common in the Sierra Nevada, Klamath Mountains, and central Oregon, whereas the Coast Ranges are relatively lacking in copper occurrences (fig. 9). Host rocks include a wide variety of igneous, sedimentary, and metamorphic rocks but few have volcanic host rocks. Although the dominant copper sulfide is chalcopyrite, a few deposits have chalcocite or bornite in addition to or instead of chalcopyrite and some oxidized ores do occur in the northern Sierra Nevada and southern Klamath Mountains. Copper is often subsidiary to gold and silver and may be associated with lead and zinc and sometimes tungsten, molybdenum, bismuth, or antimony sulfides.

NICKEL

Nonproductive nickel sulfides are most prevalent around Canyon Mountain and virtually absent elsewhere (fig. 10). The nickel minerals, millerite and niccolite, are usually associated with copper, platinum, or mercury in a metamorphic host rock.

Nickel silicate ores containing the nickel mineral garnierite are only common near the Josephine Peridotite and the Upper Paleozoic-Triassic ophiolite of the Sierra Nevada; yet, the only major United States' deposit is in the youngest ophiolite of the Klamath Mountains. The laterites are generally underlain by ultramafic rocks and are not accompanied by iron ores.

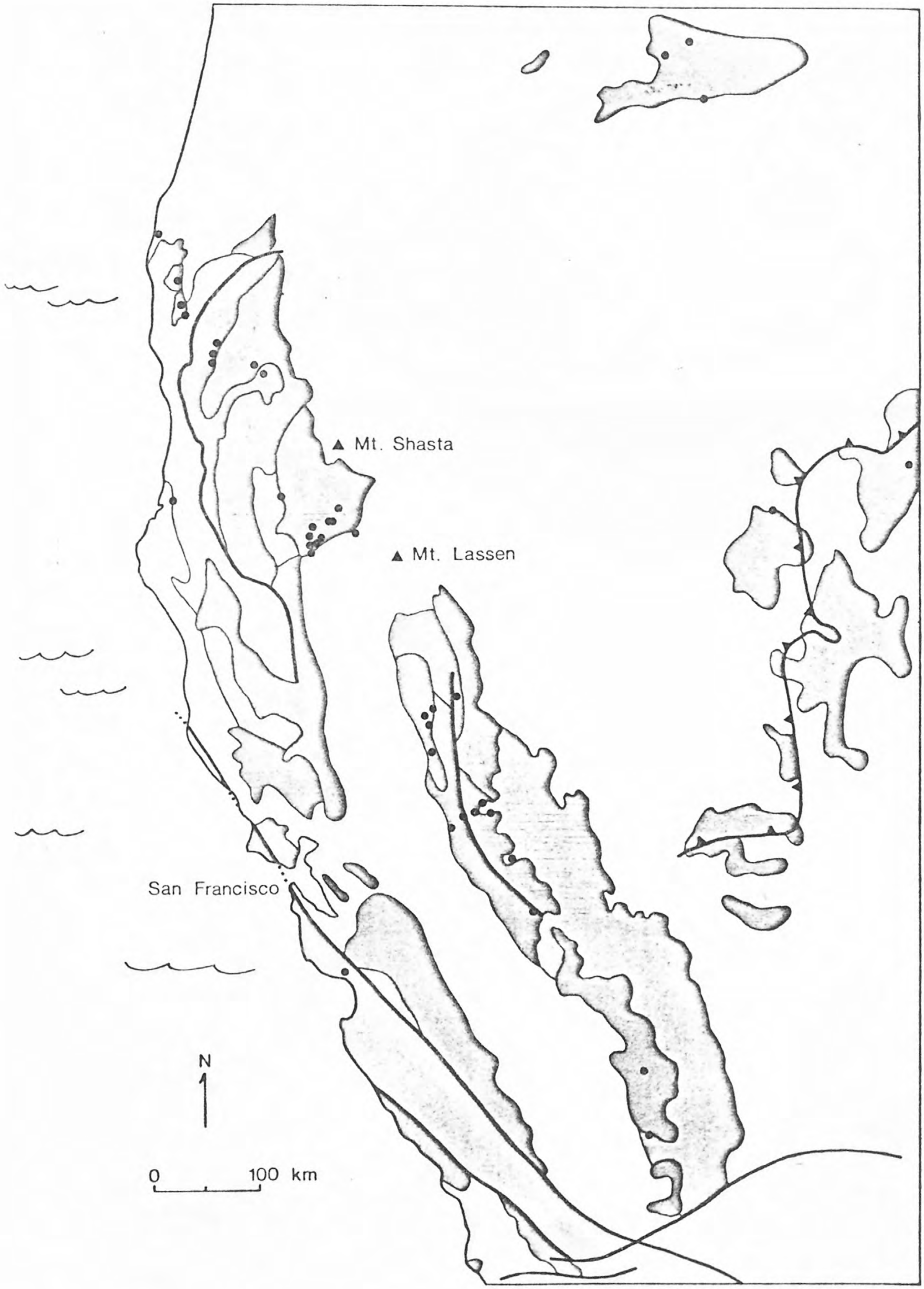

Figure 7. Distribution of iron and titanium.

Figure 9. Distribution of copper.

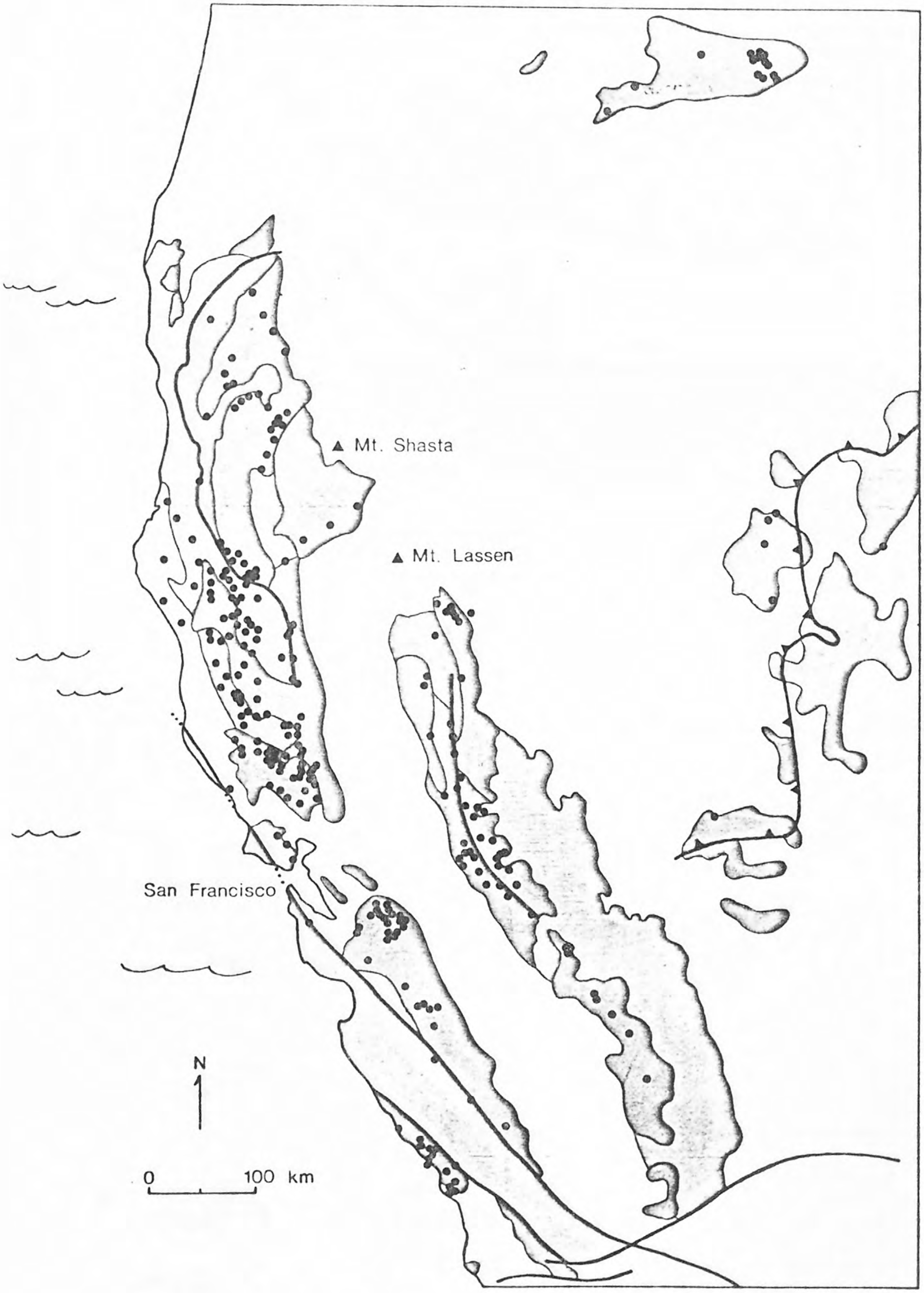

Figure 8. Distribution of manganese.

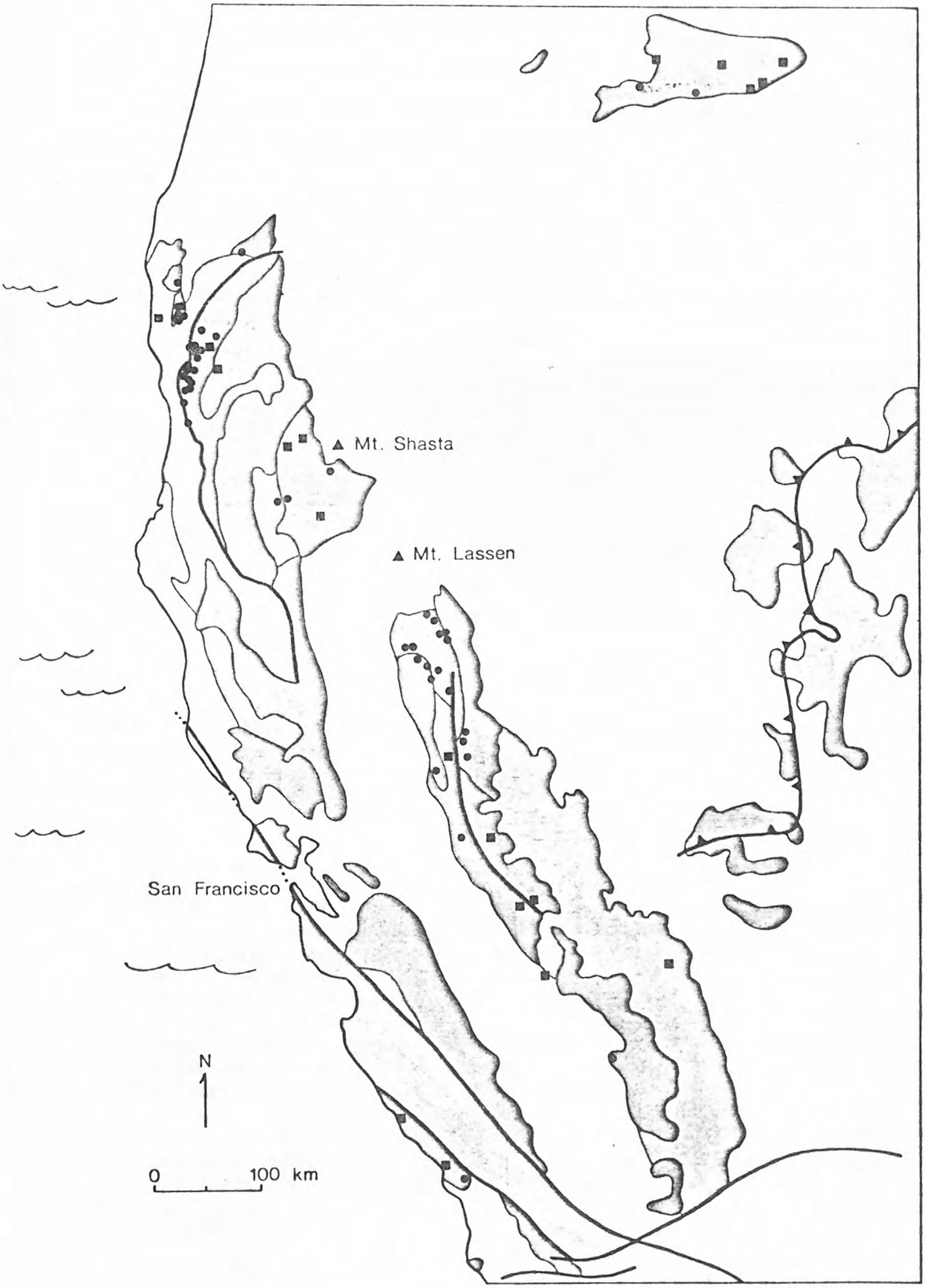

Figure 10. Distribution of nickel; square = nickel sulfides, circle = nickel silicates.

CHROMITE

Chromite is ubiquitous throughout the serpentinized bodies of all the belts (fig. 11), but few deposits produced more than 50,000 tons and most produced less than 100 tons. The chromite occurs as pods, stringers, lenses, or bands or is disseminated throughout the host massif, which is usually serpentinized harzburgite, but the chromite itself occurs in dunite pods within the harzburgite. Talc is a common associated mineral. A small amount of chromite occurs in placer and laterite deposits. Chromium to iron ratios which range from 1.5:1 to 4:1 do not show any geographic trends, and chromium to aluminum ratios are not reported in the literature.

PLATINUM

Most of the platinum deposits are placers and only two lode deposits have produced. Platinum-group metals are almost totally lacking in the Coast Ranges and near Canyon Mountain (fig. 12). The Lower Paleozoic ophiolites of the Sierra Nevada and Klamath Mountains have far fewer occurrences than the Upper Paleozoic and Mesozoic ophiolites. Placer platinum-group metals always occur with and are usually subordinate to placer gold. Lode platinum-group metals are associated with chromite rather than gold. The host peridotites are intensely serpentinized. Probably the most interesting thing I discovered while doing these maps was the distribution of platinum-group metals. Sierran deposits have more platinum plus palladium than osmium plus iridium, while the Klamath deposits have more osmium plus iridium than platinum plus palladium.

CONCLUSIONS

Now that each commodity has been briefly discussed, some broad geochemical differences between the various ophiolite belts can be pointed out. Some of these aspects may be important in unraveling the genesis and correlation of these ophiolite belts.

1. Lower Paleozoic ophiolites host nonproductive titanium deposits, the others do not.

2. Upper Paleozoic-Triassic ophiolites do not contain much asbestos or iron and titanium, but in the Sierra Nevada they do contain nickel laterites; near Canyon Mountain they contain nickel sulfides and amphibole asbestos; they are the only ophiolites in the Klamath Mountains that contain manganese occurrences.

3. Lower to Middle Jurassic ophiolites contain the productive iron and titanium deposits. Additionally, in the Klamath Mountains they contain nickel laterites near the Josephine Peridotite.

4. Upper Jurassic ophiolites do not have much copper, nickel, or platinum relative to the other belts, but magnesite is present and the large nickel deposit is in these rocks.

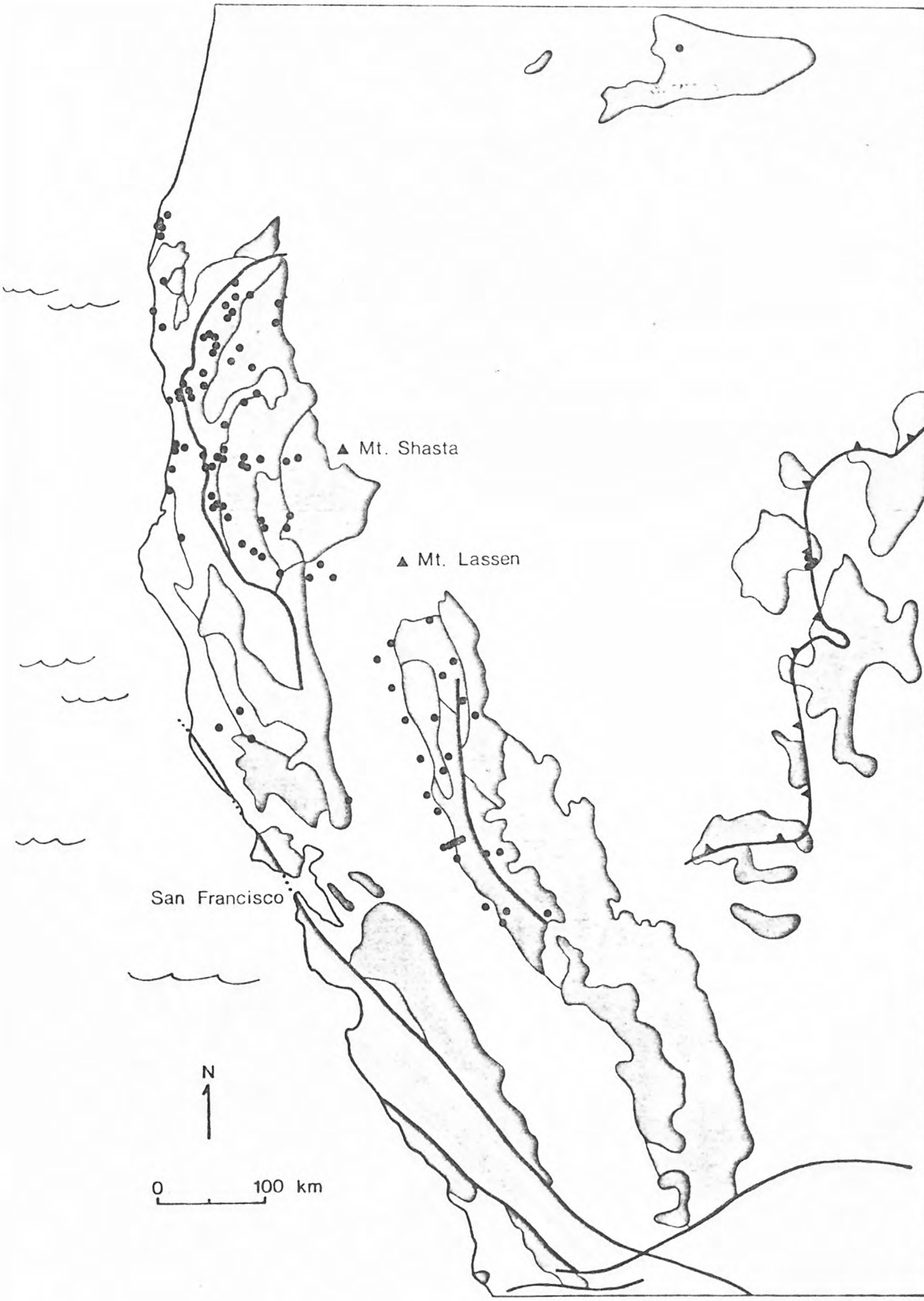

Figure 12. Distribution of platinum group metals.

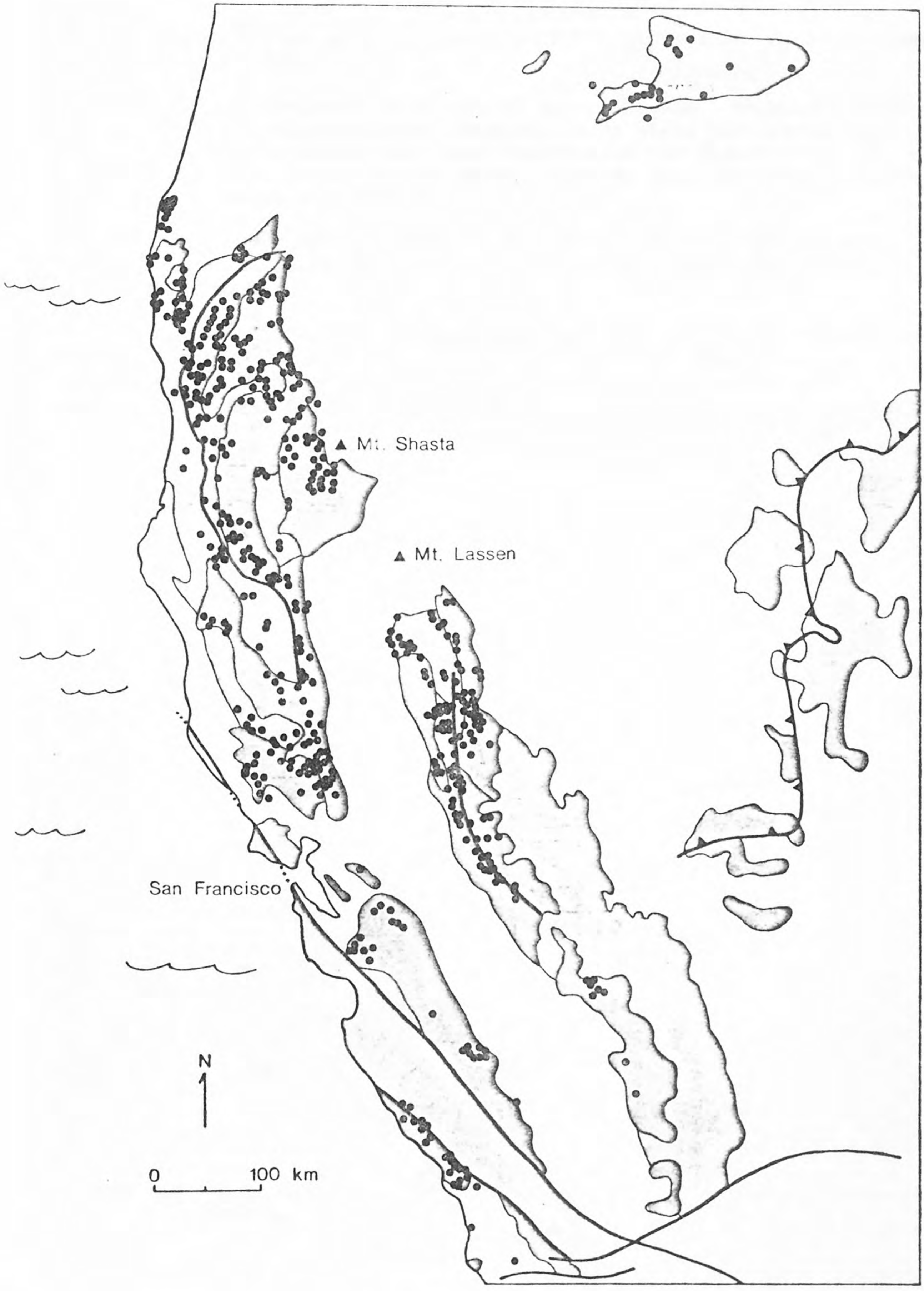

Figure 11. Distribution of chromite.

5. Magnesite and nonproductive iron and titanium occur in the southern Sierra Nevada.

6. The talc deposits occur in the Sierra Nevada. Amphibole asbestos plus volcanic-associated manganese occur along the Melones fault in the Sierra Nevada (the fault depicted in the Sierra Nevada in fig. 2). Also in the Sierra Nevada, platinum plus palladium is greater than osmium plus iridium.

7. In the Klamath Mountains, manganese is virtually absent except as mentioned above and osmium plus iridium is greater than platinum plus palladium.

Throughout this paper nothing has been said about the deposits in Nevada. That is because the ophiolitic character of these rocks is poorly understood, so it is not known how the deposits relate to the ophiolites or whether indeed they are even ophiolites.

REFERENCES

Irwin, W. P., 1977, Ophiolitic terranes of California, Oregon, and Nevada, in Coleman, R. G., and Irwin, W. P., eds., North American ophiolites: Oregon Department of Geology and Mineral Industries Bulletin 95, p. 75-92.

______1979, Ophiolitic terranes of part of the western United States: Geological Society of America, scale 1:2,500,000.