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Resource Assessment of the U.S. Bureau of Land Management's Winnemucca District and Surprise Resource Area, Northwest Nevada and Northeast California:

Resources of Industrial Rocks and Minerals

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature. Any use of trade names is for descriptive purposes only and does not imply endorsement by the USGS.

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SUMMARY

Industrial rocks and minerals have been produced for many years in the Winnemucca District, and to a lesser extent in the Surprise Resource area. The value of past production can only be estimated because marketing aspects of many commodities are kept proprietary, but probably was less than for metallic minerals. To date, production of diatomite, gypsum, and sand and gravel has been most important in the area. Geologic conditions are favorable for many industrial commodities and suggest large potential resources. Because transportation expenses are a large factor in the economics of these commodities with low unit value, exploration and development of new deposits will likely not happen until markets change or population increases in northwestern Nevada and adjacent California. Development of new mines is most likely within 10-20 miles of the Interstate 80 and railroad corridors. In the next decade increased demand, and hence incentive for development, is most likely for sand and gravel (aggregate) for construction and limestone (lime) for construction and for metallurgical use by the gold-mining industry.

INTRODUCTION

The U.S. Geological Survey (USGS) is a party to a joint interagency Memoranda of Understanding (MOU) with the U.S. Bureau of Land Management (BLM) to coordinate resource assessments and evaluations of BLM-administered lands. Resource assessments of BLM Resource Areas, conducted by the USGS under these MOU's, assist the BLM in meeting inventory and evaluation, resource-management planning, and other requirements of the Federal Land Policy and Management Act of 1976. This report is one of several to be generated as a part of resource assessment of BLM-administered lands in northwest Nevada and northeast California.

Industrial rocks and minerals are essential to our modern civilization, and some are produced and consumed in enormous quantities. The value of industrial minerals produced in Nevada was about $322 million in 1993 (Castor, 1995). The majority of this production was near the major population centers, Las Vegas and Reno, for use in highways and buildings. In order of estimated value, the most important commodities produced in Nevada are aggregate, diatomite, lime, cement, gypsum, barite, lithium carbonate, silica, clay, and magnesia (Castor, 1995). The value of aggregate, about $126 million, is second only to gold. In the Winnemucca-Surprise Resource Area (WSRA), diatomite and gypsum are the most valuable commodities produced.

There is a history of exploration and development of industrial rocks and minerals in the WSRA, with substantial production of some commodities such as diatomite, gypsum, sand and gravel. The actual value of production probably is much lower than for metallic minerals, although details are difficult to compile because many technical and marketing aspects of industrial minerals are kept proprietary. Records in general are not nearly as complete as for metals, partly reflecting tight competition on commodities having low unit values, and in cases related to market domination by a few corporations. For these and other reasons we can make only generalized comments about undiscovered resources and likely future exploration activities. Also, grade and tonnage models of industrial minerals have not been compiled as they have been for metals, and we can not estimate those parameters for the WSRA. The following assessment comments are largely geologic, empirical, and qualitative.

Most of the commodities discussed are transported to markets outside the WSRA, but a few are utilized locally. Sand and gravel, for instance, is used locally for road and other construction; this reflects both availability and the influence of transportation costs. Commodities that must be exported must be mined and milled relatively close to good roads and railroads, or transportation costs will dominate the value of the product. For many commodities, such as barite, clay, diatomite, fluorite, and others, proximity to the Interstate 80-Southern Pacific Railroad corridor (fig. 1), or the Western Pacific/Union Pacific Railroad, is important.

The history of mining in Nevada reveals that many metallic and non-metallic deposits that were mined years ago are not competitive today. There are a variety of technological and marketing reasons for these changes. The fact that a commodity was mined previously may not be relevant to predicting future mining. In discussions of some commodities, such as fluorite and sulfur, mention must be made of market dominance by deposits in other geologic settings; for some commodities, such as barite, market dominance by foreign sources also can be a factor in the viability of Nevada resources. In places the term "significant deposit" will be used to describe a deposit in Nevada that is currently competitive and important among national or world deposits. In many cases deposits may be known, or may be undiscovered within the WSRA, but not be competitive with significant deposits elsewhere.

Information on mines, prospects, and occurrences was compiled by Don Sawatzky, USGS, from digital records of the USGS Mineral Resources Data System (MRDS) and US Bureau of Mines Mineral Inventory Locator System (MILS). The MRDS database was queried for non-metallic commodities in both metallic and non-metallic records, thus many reports for 'commodities' such as fluorite, barite, or sulfur may pertain to accessory minerals in metallic mineral deposits. The records in MRDS and MILS were not confirmed by field studies, nor were any other field investigations carried out for this overview of industrial materials. Localities for non-metallic commodities shown on maps in this report have not been specifically evaluated for their economic potential; they are most useful as general indicators of where non-metallic resources may exist in the study area.

Acknowledgments. Information used in this study was compiled by Don Sawatzky of the Reno Field Office, USGS. Katharine Connors, USGS in Reno, produced the spatial information that was used to generate the commodity locality figures in this report. Comments on the manuscript were provided by Al Bush, Jeff Doebrich and Steve Ludington, USGS. Vic Dunn, BLM in Winnemucca, offered helpful assistance.

BARITE

Commodity Produced: Barite

End Use: Weighting agent in drilling muds.

Known Deposits: Rossi, Eureka Co., Argenta, Lander Co., numerous others in N-C Nevada; in WSRA, Redhouse, Anderson, Horton, and Little Britches, Osgood Mountains, are bedded-type. Barite mines, prospects, and occurrences are shown on figure 2.

Geologic setting: Beds of barite occur as laminated barite in dark gray siliceous sedimentary rocks. The rocks and barite were originally deposited in deep ocean water in the general vicinity of faults and rifts in oceanic crust. The barite is a chemical precipitate on the sea floor; enclosing rocks are mixtures of chemical sediments and clastic deposits. Age is commonly Paleozoic, but chiefly Cambrian-Devonian in northern Nevada. The main belt of rocks containing bedded barite is east of WSRA in

Lander County (Roberts Mountains allochthon), and similar rocks contain barite deposits in a structural window in the Osgood Mountains of the WSRA.

Vein deposits of barite formerly were mined in Nevada, but these can no longer compete with bedded deposits that are amenable to open-pit mining. The veins are generally less than 6 m thick and less than 100 m long. Vein deposits will not be considered further as they will not be favored for development in the future.

Economic factors: Density and purity affect processing costs and end uses. The high density of barite contributes to high transportation costs; mines and mills must be near railroads. Beneficiation, using screens, jigs, and floatation, is required to purify ore for markets.

Assessment: Bedded barite deposits are stratabound within Paleozoic marine sedimentary rocks, especially those of Cambrian-Devonian age; these rocks constitute the permissive tract. The Cambrian Preble and Ordovician Comus Formations contain known deposits and are likely to contain others. Paleozoic rocks west of Winnemucca do not contain known bedded barite deposits and appear to have low favorability compared to rocks of the Roberts Mountains allochthon to the east.

References: Brobst, 1983; Papke, 1984; Clark and Orris, 1991.

BERYL

Studies were made in the 1950's of beryl in the Humboldt Range (fig. 1), where it occurs in several scheelite deposits. There was no production of beryl from the tungsten deposits. The prominent beryl crystals, up to 10 cm long, appear to be better suited for mineral collectors than as a potential beryllium resource.

Reference: Johnson, 1977.

CLAY

Commodity produced: Clay (montmorillonite, fullers earth, kaolin, halloysite, etc), bentonite.

End uses: drilling mud, oil refining, absorbents (pet litter), industrial fillers, ceramics.

Known deposits: Amargosa Valley, Nye county, active producer; In WSRA, active production of halloysite from deposit about 30 km north of Pyramid Lake in Washoe Co; Rosebud Canyon; Barrett Springs; Willard district; S. Trinity Range; Spring Valley district. Known mines, prospects, and occurrences are shown on figure 3.

Geologic setting: Clay deposits can form in many rock types and settings. Most deposits in Nevada are found in hydrothermally altered volcanic rocks or in fine-grained clastic lacustrine rocks. Derivation from glassy volcanic ash or tuffs is common. Age is mostly Miocene to Pliocene.

Economic factors: One of the larger specialty clay deposits (Pinite mine) in the WSRA produced 3,000 tons prior to 1970; this is very small deposit by national standards. Value of deposit depends on details of mineralogy and technical properties (plasticity, cation exchange capacity, etc) and purity--information that is not available in public files. Impurities such as quartz and calcite generally must be removed for most end uses. For large tonnage production, proximity to transportation is important.

Assessment: The permissive tract for clay deposits is coincident with Miocene-Pliocene volcanic rocks and volcaniclastic sediments. Local features such as faults and hydrothermal alteration, required to make deposits, have not been compiled to outline favorable areas. Large amounts of generic, low purity clays usable as absorbents ('kitty litter') probably are present. We lack specific information to assess the occurrence of technical, high purity clays for special end uses.

References: Murray, 1983; Papke, 1970; Johnson, 1977.

DIATOMITE

Commodity produced: diatomaceous earth.

End uses: Filters, and fillers in food and industrial materials.

Known deposits: Clark operation, Storey County; Gefco mine, Mineral County; in WSRA, Colado operation, Velvet district (Trinity Range) w. of Lovelock; S. Trinity Range ne. of Bradys Hot Springs. Known mines, prospects, and occurrences are shown on figure 4.

Geologic setting: The known and anticipated deposits in NW Nevada are of the lacustrine type that formed in freshwater lakes created by Miocene extensional faults. The large amount of silica required for growth of diatoms is derived from nearby silicic volcanic rocks and hot springs. Development of thick and pure sequences of diatom deposits requires periods of tectonic stability to minimize input of clastic detritus. Preservation of delicate diatom frustules (that determine the special technical properties of diatomite) requires quiet-water deposition and minimal diagenesis (heat, burial, and cementation). Age of deposits in NW Nevada is Miocene to Recent.

Economic factors: Cover by younger rocks and alluvium must be less than about 50 m to allow inexpensive mining by open-cut methods. Technical properties that determine market value are generally proprietary. The high bulk-low density of crude and refined diatomite requires special handling methods; proximity to transportation corridors (railroad and I-80) is required. Crude diatomite can be trucked as far as 50-100 km to mills, especially if water content is low (as after solar drying in NW Nevada).

Assessment: Permissive tracts are associated with Miocene normal fault zones and volcaniclastic-sedimentary rocks. Large proven and inferred resources remain for mining in the Trinity Range (Nash, 1995), and exposed diatomite north of Bradys Hot Spring is highly prospective. Many diatomite occurrences in the western part of the WSRA appear to be too thin to be viable.

References: Kady, 1983a; Shenk, 1991; Lenz and Morris, 1993; Nash, 1995

DUMORTIERITE

Commodity produced: Dumortierite (Aluminum boro-silicate)

Uses: Ceramics, spark plugs.

Known deposits: in WSRA, Champion mine, Oreana.

Geologic setting: This is a very rare deposit type and is no longer of high development interest; no other dumortierite deposits in the world have been developed. Dumortierite forms by contact metamorphism of strata having unusually high aluminum content. Boron probably comes from nearby intrusions by so-called pneumatolytic processes. The precursor rock, generally volcanic, attains an unusual composition by hydrothermal alteration or weathering prior to metamorphism; in the Humboldt Range the host rock is an unusual unit of the Triassic Rochester rhyolite that is rich in micas, alumino-siliocate minerals, and tourmaline. A large pluton and moderate depth are required to attain the narrow metamorphic field of dumortierite. Age is Jurrasic-Cretaceous.

Economic factors: The Champion mine produced about 5,000 tons prior to 1950. Formerly in demand for special ceramic applications, this material is no longer in high demand. Impurities, which are abundant in this environment, must be removed by milling; the toughness of these rocks makes milling costly. There possibly is a small, specialty market.

Assessment: The known deposit in the W. Humboldt Range formed in the metamorphic aureole of a Cretaceous pluton, but the key ingredient was the wallrock of unusual composition. The permissive tract is the contact zone between Jurassic-Cretaceous plutons and Proterozoic-Mesozoic rocks. No reserve estimates were made public when the Champion mine closed in 1950. Additional small deposits are known and additional undiscovered ones probably exist in the Humboldt Range. Exploration and development of new deposits in unlikely.

References: Kerr and Jenney, 1935; Wallace and others, 1969 (map); Johnson, 1977, Bennett and Castle, 1983.

FLUORSPAR

Commodity produced: fluorite (CaF_2)

End uses: Hydrofluoric acid, ceramics, and metallurgical flux.

Known deposits: Daisey mine, Nye Co., largest producer in Nevada (200,000 tons); in WSRA, none known to have production; the numerous occurrences of fluorite gangue in metallic ores are not viable fluorspar resources. Known mines, prospects, and occurrences are shown on figure 5.

Geologic setting: Deposits known in NW Nevada are vein-type, in or near intrusive igneous rocks. The deposits form from warm to hot hydrothermal solutions with a magmatic component that provides fluorine. Open-standing fault and breccia zones, and wide replacement zones are required to make sufficient tonnage and grade. Limestones are a favored host for the larger deposits in Nevada. Age is that of intrusions, Cretaceous to Miocene.

Economic factors: Although fluorite occurs in many hydrothermal metallic ore deposits, as at Majuba Hill, it rarely constitutes more than a potential by-product despite apparent abundance. Viable deposits contain zones >10 m wide containing >50% fluorite. Enclosed minerals such as quartz and pyrite must be easily removed by milling or they penalize value and applications. Production would be exported to distant markets, thus proximity to prime transportation corridors is required.

Assessment: Permissive tract is Cretaceous to Miocene intrusive rocks and nearby wallrocks, especially limestone. The permissive tract is the same as that of porphyry Cu-Mo deposits, plus volcanic centers such as McDermitt that have ring-dike intrusions. The coincidence of fluorite occurrences with zones of hot springs is misleading as this environment is not likely to produce large deposits.

The probability of a significant fluorspar deposit in the WSRA is low. The major world deposits tend to be associated with intracratonic rifts. The largest fluorspar resource (high tonnage, sub-economic grade) is at McCullough Butte near Eureka, NV, and is associated with a lithophile-element enriched two-mica granite of Cretaceous age (Barton, 1988). Cretaceous two-mica granites enriched in lithophile elements are known in at least two localities in the WSRA at New York Canyon, Stillwater Range, and Rocky Canyon, Humboldt Range, but fluorspar deposits have not been recognized in them (S. Ludington, USGS, written commun., 1995).

References: Fulton and Montgomery, 1983; Barton, 1987; Papke, 1979.

GEMS AND SEMI-PRECIOUS STONES

Commodities produced: Opal, turquoise, specimen gold, etc.

End uses: Jewelry, collections.

Known deposits: In WSRA, gems produced from Black Rock and Virgin Valley areas; specimen gold is recovered from several former gold vein districts. Known mines, prospects, and occurrences of gems are shown on figure 6.

Geologic setting: These materials come from a wide variety of geologic terranes. In Nevada many come from Tertiary volcanic rocks, such as opal in Virgin Valley. Deposits tend to be small and highly localized, thus difficult to predict from regional geology.

Economic factors: Unlike most other commodities reviewed here, these have fairly high unit value, so transportation is not a factor. Deposits are small and generally must be mined carefully to avoid damaging materials--thus they are labor intensive. New electronic technology in metal detectors allows detection of gold crystal specimens through a foot or more of rock or alluvium.

Assessment: Tertiary-Recent volcanic rocks are permissive for opal deposits; The Black Rock Desert and Virgin Valley areas are most favorable according to past prospecting success. Tertiary volcanic rocks are most favorable for specimen gold, as in the Seven Troughs, Awakening, and National Districts; recent discoveries are confidential.

References: Willden, 1964

GYPSUM

Commodity produced: gypsum

End uses: wallboard, plaster products, Portland cement, fertilizer, industrial filler.

Known deposits: James Hardie and PABCO operations, near Las Vegas; in WSRA, U.S. Gypsum operations at Empire (south of Gerlach) increased to about 400,000 tons in 1993 (largest in Nevada); prospects E and SE of Lovelock in Muttlebury and Table Mountain districts. Known mines, prospects, and occurrences of gypsum are shown on figure 7.

Geologic setting: The known deposits in NW Nevada are of marine origin, but non-marine (lacustrine) type are known in western U.S. The deposits form in marginal marine basins, where periodic influx of sea water provides salts that are precipitated during stages of evaporation. The gypsum beds can be thick (> 100 m) and widespread, but tend to be very poorly exposed at the surface because they are easily weathered. Associated evaporite beds include limestone, dolomite, or salt, and interbedded clastic rocks are redbeds. Much primary gypsum is transformed to anhydrite during diagenesis, but tends to be rehydrated close to the surface. The known deposits in WSRA are in the Jungo and Black Rock terranes; age is Jurassic-Triassic.

Economic factors: Surface weathering can improve, degrade, or destroy a deposit depending on the type of alteration. Impurities from deposition or alteration must be minor and easily removed in minimum-cost beneficiation. Mineable deposits need to be close to the surface (<50 m) as most mining is by open-cut methods, although large and thick deposits can be mined underground. The high weight:value ratio requires efficient rail or highway transportation of product.

Assessment: Permissive tract is Jurassic-Triassic marine sedimentary rocks of Jungo or Black Rock terranes within about 200 m. of surface. The evaporite section appears to be at the top of the sequence, but structural complexities complicate prediction of where this zone will occur near the surface. Drilling is required to define thickness and purity of gypsum as part of resource definition. On-strike extensions and new deposits are likely in the Selenite Range south of Gerlach and West Humboldt Range east of Lovelock.

References: Johnson, 1977; Appleyard, 1983, Raup, 1991.

LIMESTONE

Commodity produced: lime, Portland cement, limestone.

End uses: Cement, glass, soil additive, chemicals, crushed aggregate, flux for smelting.

Known deposits: Pilot Peak, near Wendover; Apex mine, ne. of Las Vegas; in WSRA, Min-Ad operation in northwestern Sonoma Range, near Winnemucca; prospects in Humboldt Range. Known mines, prospects, and occurrences of limestone are shown on figure 8.

Geologic setting: Limestone appropriate for these deposits tend to form on platforms on continental margins. Strata suitable for Portland cement have clay as impurities or interbedded with limestone. Appropriate compositions are in Triassic autochthon east of Fencemaker thrust, including the Star Peak Group and the lower part of the Auld Lang Syne Group where it is carbonate-bearing. Age is chiefly Permian in Golconda allochthon, and Triassic in Triassic autochthon.

Economic factors: Rocks should be low in magnesium and iron for most end uses. Transportation is a major cost factor, thus proximity to major rail and truck routes is necessary. Natural gas pipeline required for kilns. Note: Huge growth in gold mining in northern Nevada requires large supply of lime for pH control in cyanide mill and heap-leach processes; most lime is currently supplied from sources outside of WSRA, such as northeastern Nevada near Wendover.

Assessment: Rocks of the Golconda allochthon and the Triassic autochthon are permissive for limestone deposits. The Min-Ad quarry in Sonoma Range appears to be in Auld Lang Syne Formation (Triassic autochthon), which generally contains minor carbonate beds. Favorable units are in the Humboldt and Sonoma ranges.

Reference: Johnson, 1977.

LITHIUM

Commodity Produced: Lithium (hectorite clay)

End uses: cosmetics, drilling fluids, ceramics, lubricants, batteries.

Known deposits: Lithium brine near Silver Peak, Esmeralda County; In WSRA, several hectorite prospects in McDermitt caldera. Known mines, prospects, and occurrences of lithium are shown on figure 9.

Geologic setting: Lithium-rich clay minerals (hectorite) form by diagenesis or hydrothermal alteration of volcanic glass. Optimum conditions are created where alteration is within a closed basin formed by block faults or caldera ring faults. At McDermitt caldera, highest concentrations of lithium are in caldera moat-filling volcaniclastic sedimentary rocks. Lithium is postulated to be leached during alteration and concentrated in the basin, eventually becoming incorporated in hectorite. Age is Tertiary to Recent.

Another setting for lithium deposits is possible in the WSRA: Li-rich playa brines. These are known from playas elsewhere in Nevada (as near Silver Peak) and are a major by-product source of lithium at Searles Lake, CA. We have insufficient information to evaluate this potential environment that possibly would pertain to playas in the western and southwestern parts of the study area (Black Rock Desert, Humboldt, and Carson sinks).

Economic factors: The volcanic-dominated basins possibly would produce by-products such as Hg, U, zeolites, and clays. However, such by-products can contaminate Li-rich clays and limit their applications. Despite Li concentrations as high as 0.68 percent, technology for large-scale extraction of Li from hectorite has not been developed. A large production facility would need to be close to good transportation facilities for either Li-clay or a Li-salt produced at site.

Assessment: The permissive tract is Tertiary volcanic rocks, as for diatomite and clay deposits. The more favorable areas would have normal or ring faults to create grabens or caldera moats and to focus alteration and solutions; intrusive plugs along those bounding faults drive fluid flow. The McDermitt caldera is the best structural setting for these deposits; other postulated calderas in the WSRA do not have well developed moats.

References: Asher-Bolinder, 1991; Rytuba and Glanzman, 1979.

ORNAMENTAL STONE

Commodity produced: Ornamental stone; building stone.

End uses: Building materials.

Known deposits: Cretaceous Aztec Sandstone near Las Vegas; Tertiary tuff near Beatty; and small local quarries elsewhere in Nevada. There has been no major production from the WSRA.

Geologic setting: These materials generally come from sedimentary or volcanic units that have well-bedded rocks with a prominent parting or coloration. Sandstone and volcanic-sandstone are most commonly mined. Age is generally Cretaceous or Miocene-Recent.

Economic factors: Deposits must be at the surface to allow open-cut mining, and undeformed (unbroken). Low unit value and weight require good transportation and proximity to end-use market. Mining is low volume, and labor intensive.

Assessment: Permissive tract is Miocene volcanic-volcaniclastic rocks, and Triassic Koipato volcanic rocks.

PERLITE

Commodity produced: Perlite

End uses: aggregate in concrete, specialty concrete, insulation, filters, filler.

Known deposits: Wilkin operation, Caliente, Lincoln County; in WSRA, west of Lovelock. Known mines, prospects, and occurrences are shown on figure 10.

Geologic setting: Perlite is a hydrated volcanic glass, generally silicic composition in domes or plugs. Hydration is produced by contained magmatic water or more commonly from surficial water such as a lake or rain. Age is Miocene to Recent.

Economic factors: Water of hydration in volcanic glass causes expansion to a very light, frothy product when the rock is heated to 800-1200 °C. A few large mine complexes dominate U. S. Production. A glassy volcanic body must be of sufficient size and uniform composition to permit bulk mining; clay alteration products degrade product and must be eliminated by milling or selective mining. Expansion, at mine or end use site, requires natural gas for kilns. Proximity to railroad or Interstate highway is required for significant production.

Assessment: Permissive tract is Miocene-Recent volcanic rocks, as for clay and diatomite deposits. Individual domes or plugs are too small to be shown on regional geologic map; local mapping and testing of volcanic rocks is required.

References: Papke, 1973; Kadey, 1983b.

PUMICE

Commodity produced: Pumice

End uses: Abrasives, lightweight cement aggregate, concrete building blocks.

Known deposits: In WSRA, occurrences west of Lovelock (Velvet district). Known prospects and occurrences of pumice are shown on figure 11.

Geologic setting: The hardness and low density that are special properties of pumice are created by vesicular texture in silicic volcanic and pyroclastic rocks. Rocks that are highly vesicular generally form in explosive eruptions, with sub-aqueous or sub-aerial deposition. The pumice deposits can be small to immense cones, or lateral sheets extending from vents. Many beds of economic interest are very thick (to 15 m), well sorted, and unwelded. Age generally is Tertiary to Recent.

Economic factors: Purity, thickness, and lack of consolidation are major factors. Viable material should be amenable to bulk mining and simple screening. Foreign materials and hydrothermal alteration products should be minor. Low-cost transportation is required.

Assessment: The permissive tract is Tertiary volcanic and volcaniclastic rocks, as for clay and diatomite deposits. Volcanic vents, where known, are favorable sites worthy of detailed mapping and sampling.

References: Peterson and Mason, 1983

SAND and GRAVEL

Commodity produced: Sand, gravel, aggregate, road base.

End uses: Concrete, roads and railroads, construction, and numerous other uses.

Known deposits: Large mines near Reno and Las Vegas; in WSRA, Gold Butte district, sw. of Lovelock, many smaller quarries for local uses. Known mines and quarries are shown on figure 12.

Geologic setting: Uncrushed aggregate must be free of fine-grained clays and 'dirt', unconsolidated, and have grains that are resistant to abrasion and chemical attack. For certain end uses, grain shape and size gradation are important. Aggregate used in concrete must be resistant to alkalis. Favorable environments include modern and paleo-stream channels, beach terraces, and alluvial fans. Quartzite and other hard, siliceous source rocks are favorable. Age is generally Pliocene-Recent.

A different deposit type, weathered 'granite' (generic rock name), often makes excellent material for road construction. This material is found in relatively small weathered and altered zones in granitic and volcanic rocks. Clay minerals in these altered rocks create material that packs well.

Economic factors: The low unit value of this commodity requires that deposits be close to end uses; inexpensive transportation is a prime requirement. The large quarries southwest of Lovelock are 2-4 km from the Southern Pacific Railroad. Because sites tend to be close to uses, local zoning and land-use regulations can be factors. Geologic aspects include grain composition and strength, sorting, consolidation, and shallow cover.

Assessment: The permissive tract for this commodity is Quaternary alluvium and Quaternary-Tertiary older alluvium. Favorable areas are Lahontan beach terraces at about 4300-4400 ft elevation that contain reworked, well sorted gravel deposits. Weathered 'granite' is found in altered intrusive rocks and volcanic domes; moderate clay alteration is essential and must be determined at the site.

References: Dunn, 1983.

SULFUR

Commodity produced: sulfur

End uses: Sulfuric acid, chemicals, fertilizer, paper products, explosives.

Known deposits: in WSRA, near Sulphur (former production). Known mines, prospects, and occurrences of sulfur are shown on figure 13.

Geologic setting: The known fumarole (also called solfotara) deposits in Nevada are the fumarole-type, which tend to be smaller than the salt dome-type. The fumarole deposits of sulfur form in vents of volcanoes where native sulfur precipitates in vesicles, breccia, and other open volcanic structures. Deposits are tabular to pipe-like, with dimensions in the range of 10-100 m (small). Sulfur is a fairly common accessory in altered rocks at mercury and precious metals deposits, but these occurrences are not significant for sulfur production. Age is Miocene to recent.

Sulfur is also produced from pyrite concentrates, such as from massive sulfide deposits. This has not been done in Nevada. By-product production of sulfur from metallic deposits, or from smelter gases, is common today but will not be considered here.

Economic factors: Fumarole deposits tend to be small in size, and rich in As, Sb, Se, and Hg minerals that are costly to remove. The efficient Frasch process used in salt domes generally can not be used because the rocks are too permeable. Because the end product is exported, deposits should be near efficient transportation routes.

Assessment: Most database reports of sulfur are for accessory occurrences in epithermal metallic ore deposits that are not reliable guides to mineable sulfur deposits. The permissive tract for fumarole deposits is Miocene-Recent volcanic rocks; favorable zones would be volcanic centers of strato-volcanos. Sulfur deposits are part of intense hydrothermal alteration systems that produce prominent, colorful outcrops rich in clays, alunite, and iron oxides (as at Sulphur). These alteration areas have been thoroughly prospected for gold-silver-mercury deposits. Undiscovered deposits within 200 m of the surface are probably either very small or covered by younger rocks or alluvium. Considering the unfavorable economics relative to salt-dome-type deposits, it is unlikely that this deposit type will be pursued as an exploration target. The probability of a significant deposit is low.

References: Willden, 1964; Barker, 1983; Long, 1991

ZEOLITES

Commodity produced: zeolites (analcime, chabazite, clinoptilite, mordenite, phillipsite)

End uses: Ion exchange and absorbent applications.

Known deposits: In Nevada, Calico Hills and Yucca Mountain, Nye Co; Eastgate, Churchill County; in WSRA, occurrences in Tobin and Trinity Ranges, Trout Creek Mountains. Known prospects and occurrences of zeolites are shown on figure 14.

Geologic setting: Zeolites form during diagenetic alteration of silicic glass in tuffs and volcaniclastic rocks. Deposits form in tuffaceous rocks deposited in subaerial, submarine, and lacustrine environments, generally by the action of alkaline pore fluids. Deposits of the alkaline lake-type are most productive and predictable along rifts and block-faulted basins. Age is Paleozoic to Recent, but most are Tertiary.

Economic factors: As with clay deposits, value of deposit and end uses are determined by details of mineralogy (Si:Al ratio, exchangeable cations, and cation exchange capacity); this information requires special tests and generally is not available in public records. Impurities such as quartz and calcite generally must be removed by beneficiation. Most mining is by open-cut methods, and require less than about 30 m of cover to be economic.

Assessment: Permissive tract is similar to those for other commodities associated with Tertiary volcanic and volcaniclastic rocks (such as diatomite, clays, perlite). Zeolite deposits may be associated with deposits of clay or perlite. Zeolite occurrences are reported in the Tobin Range, Trout Creek Mountains, and Trinity Range; we lack detailed information to evaluate the significance of these occurrences.

References: Johnson, 1977; Sheppard, 1991.

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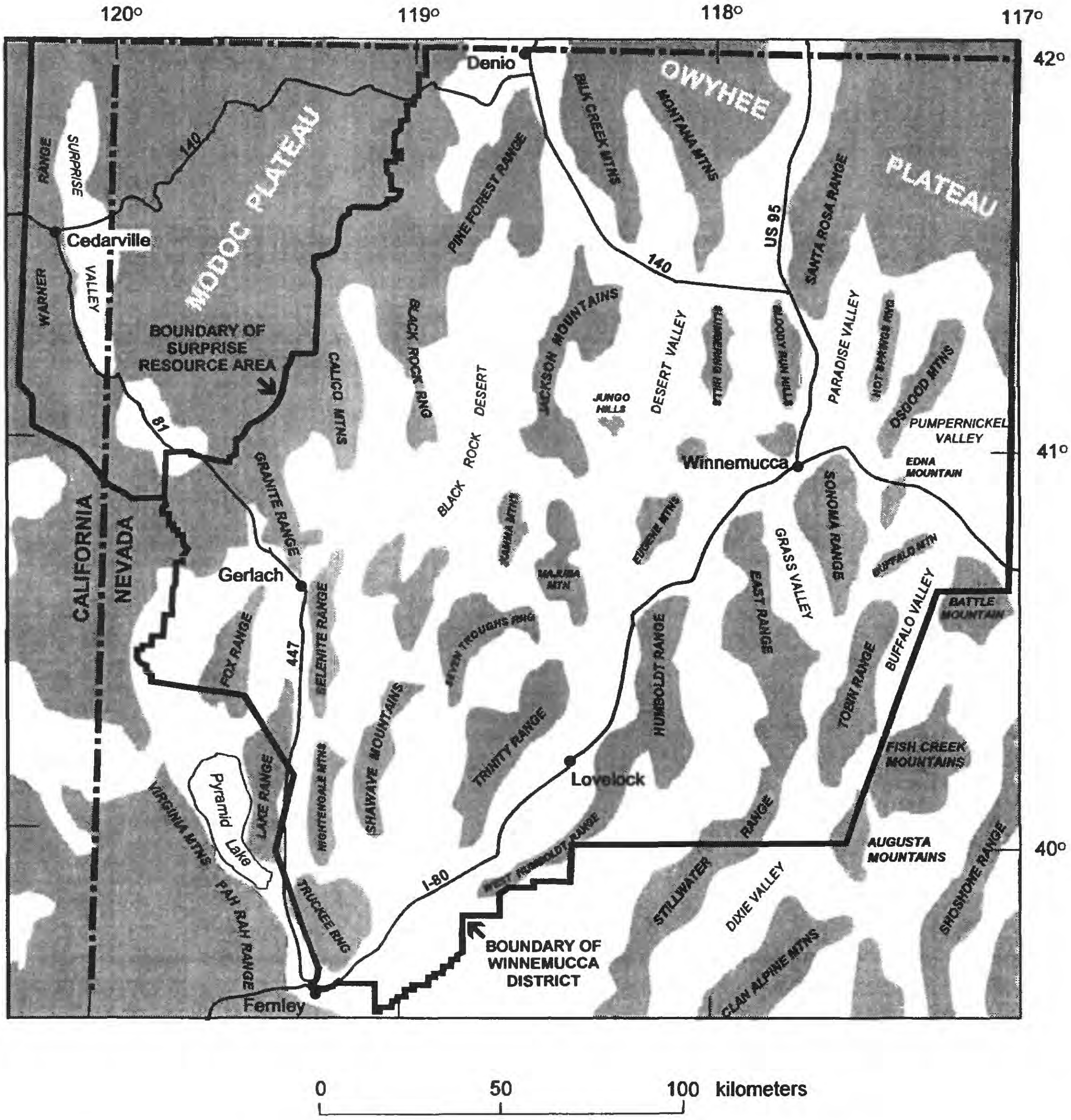

Figure 1. Major geographic features in the study area

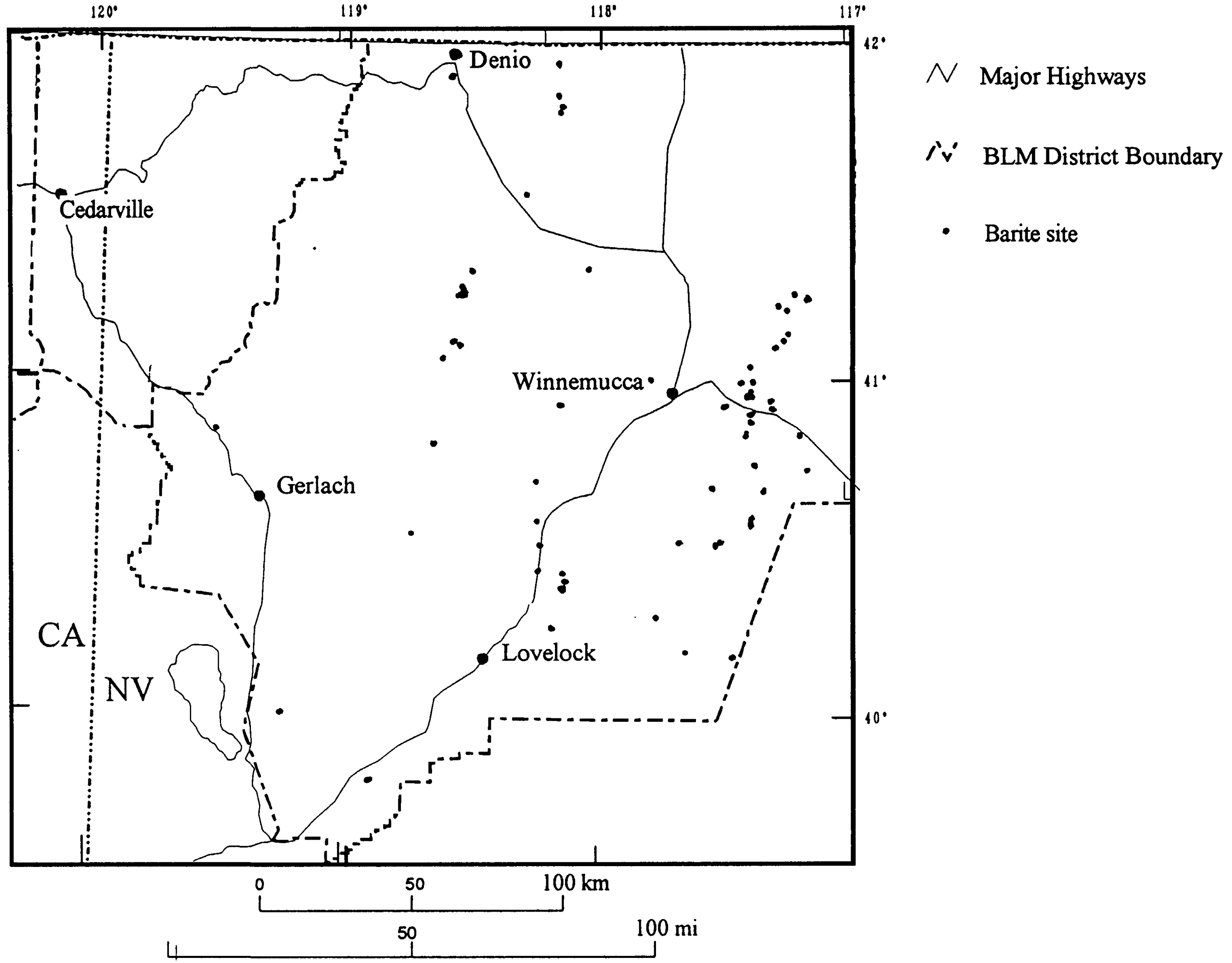

Figure 2. Location of known mines, prospects, and occurrences of barite in the WSRA. Information from MRDS and MILS databases

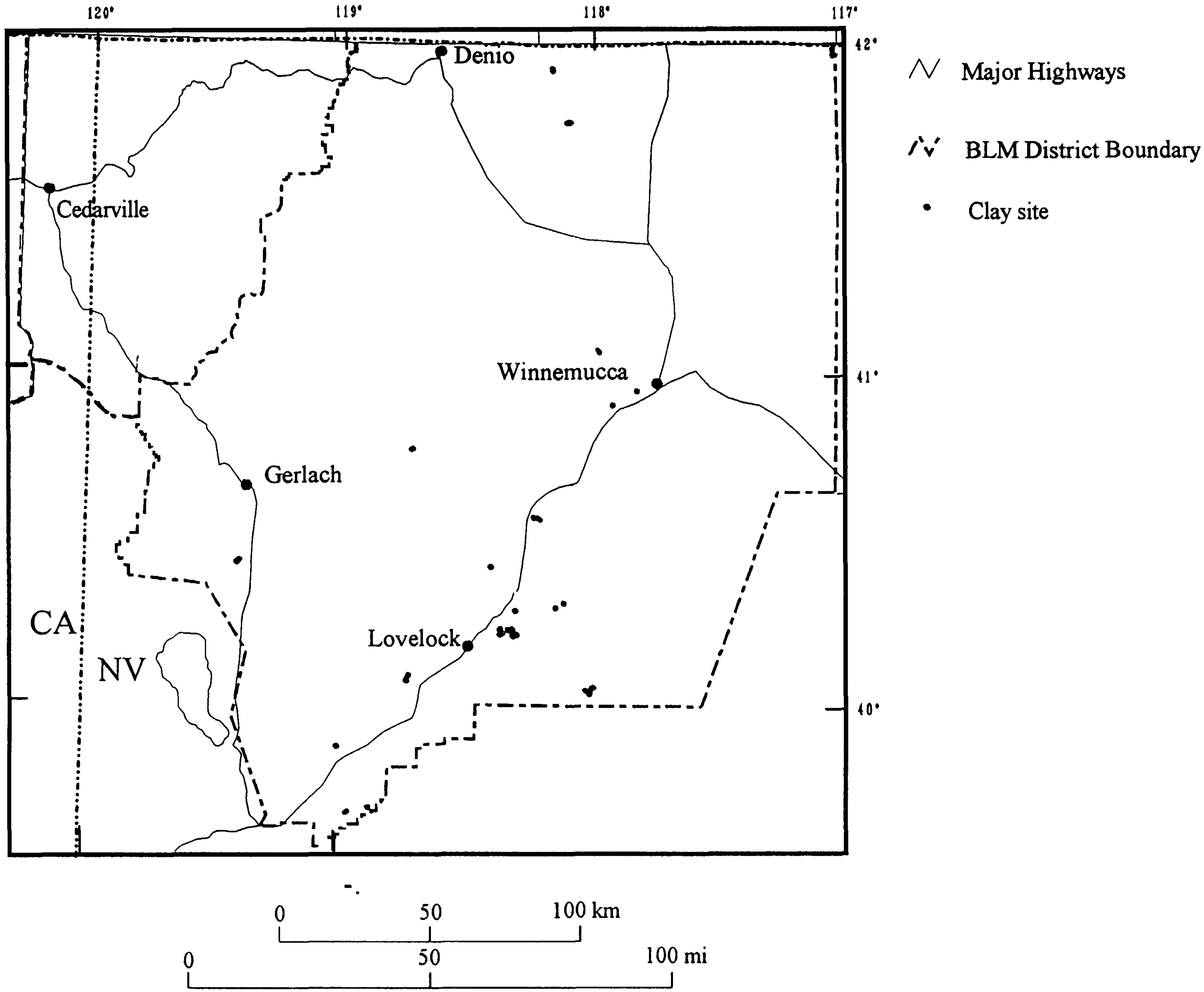

Figure 3. Location of known mines, prospects, and occurrences of clay in the WSRA. Information from MRDS and MILS databases

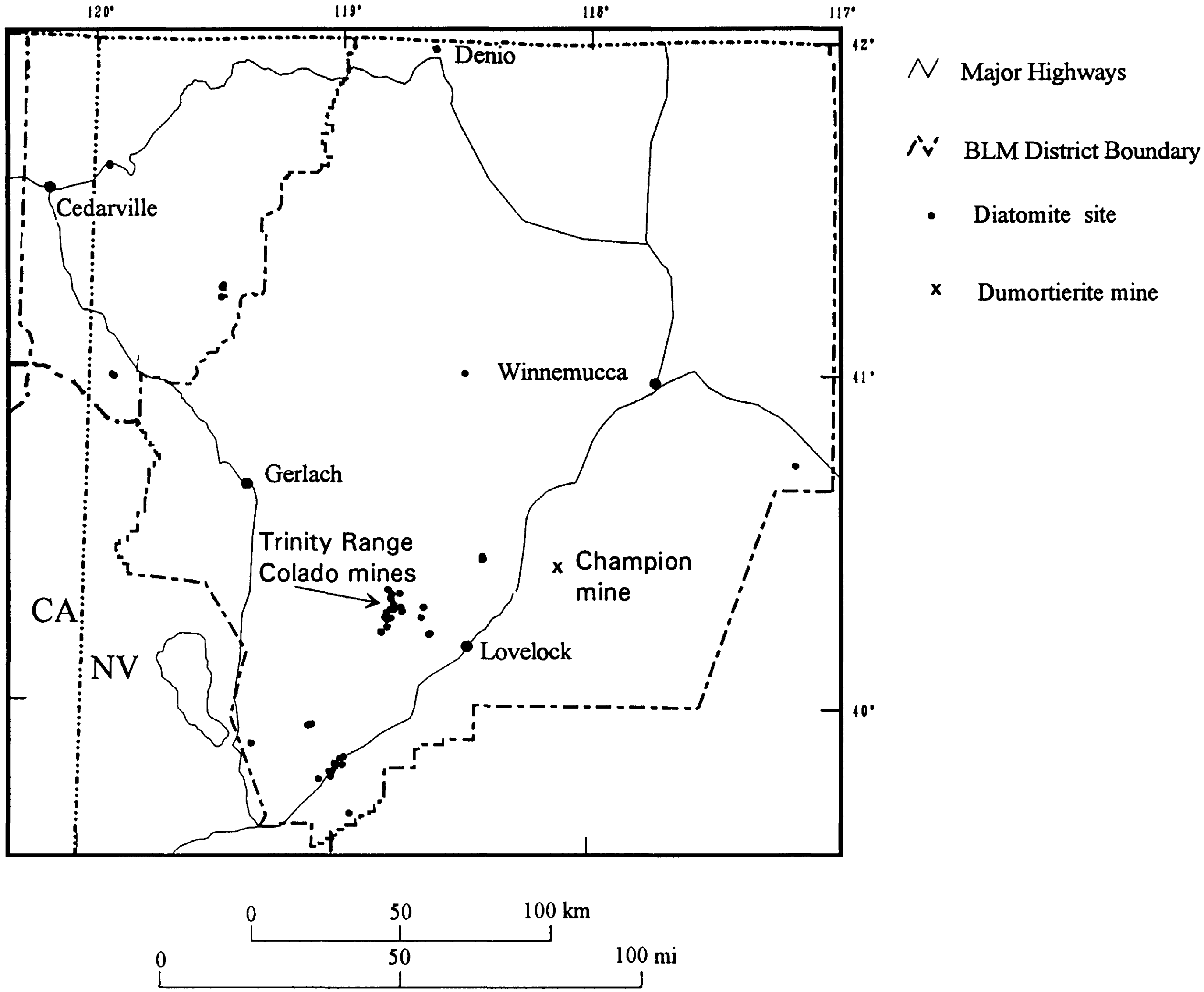

Figure 4. Location of known mines, prospects, and occurrences of diatomite in the WSRA. Information from MRDS and MILS databases. Also shown is the location of the Champion dumortierite mine.

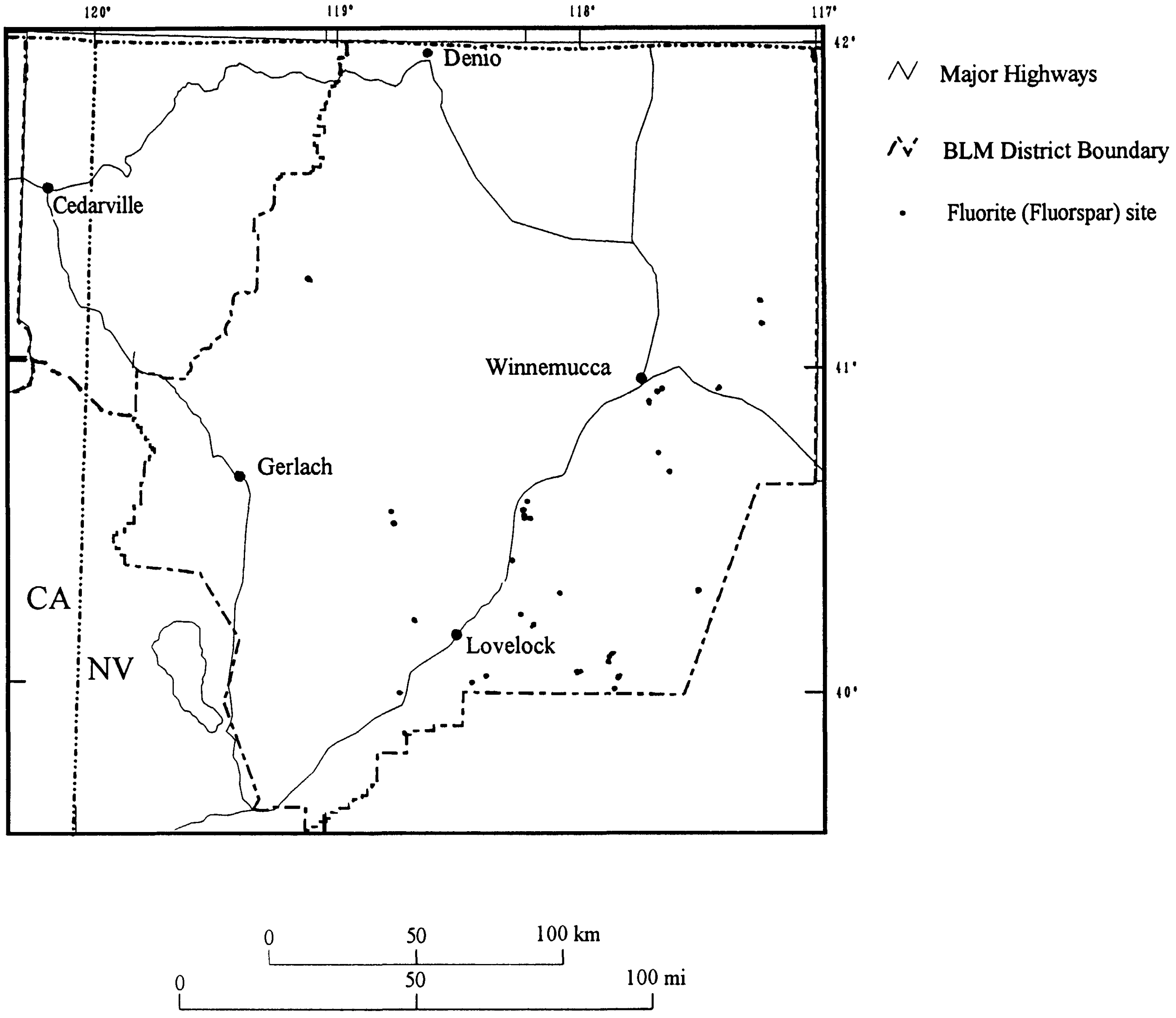

Figure 5. Location of known mines, prospects, and occurrences of fluorite (or fluorspar) in the WSRA. Information from MRDS and MILS databases.

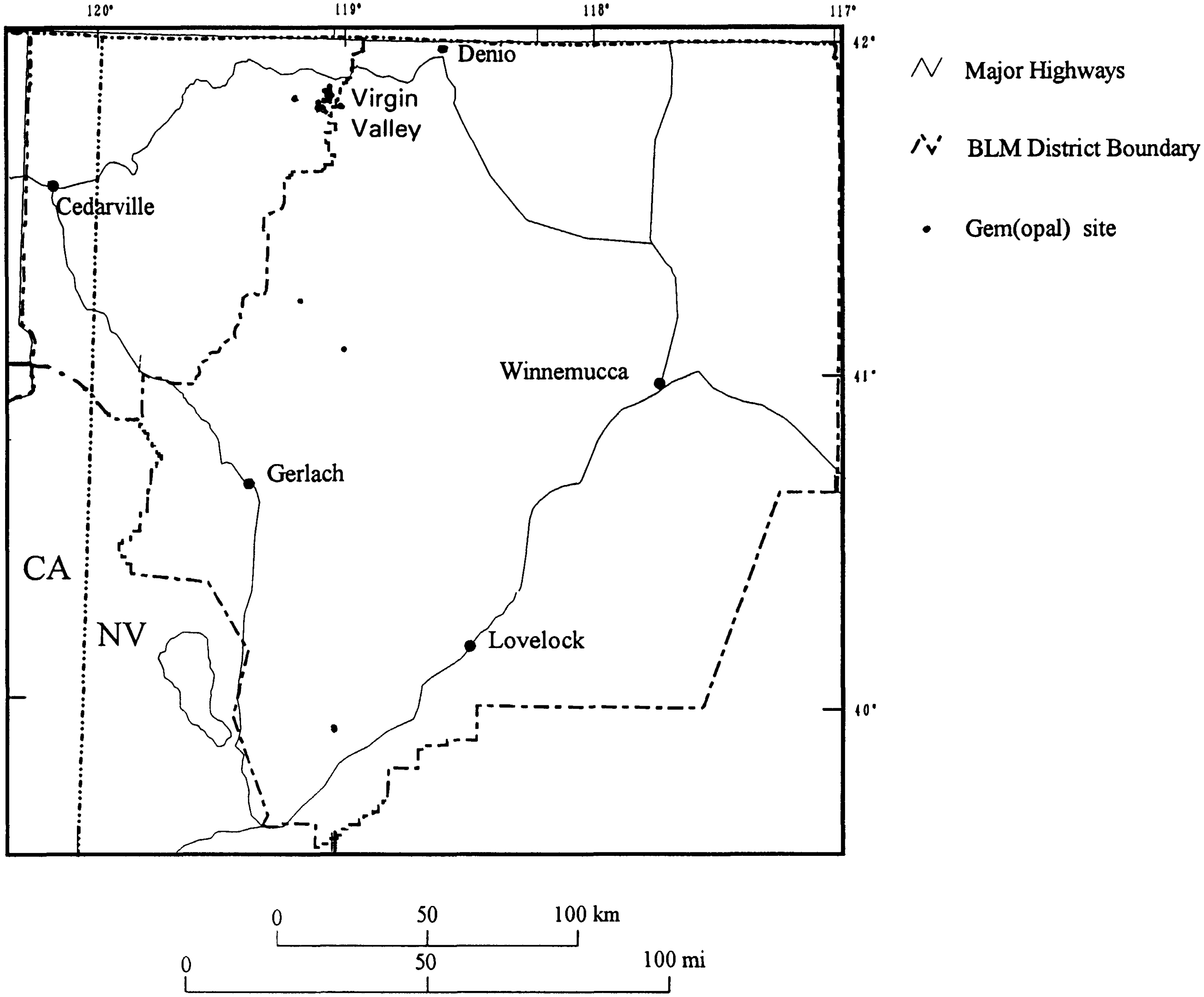

Figure 6. Location of known mines, prospects, and occurrences of gems (chiefly opal) in the WSRA. Information from MRDS and MILS databases.

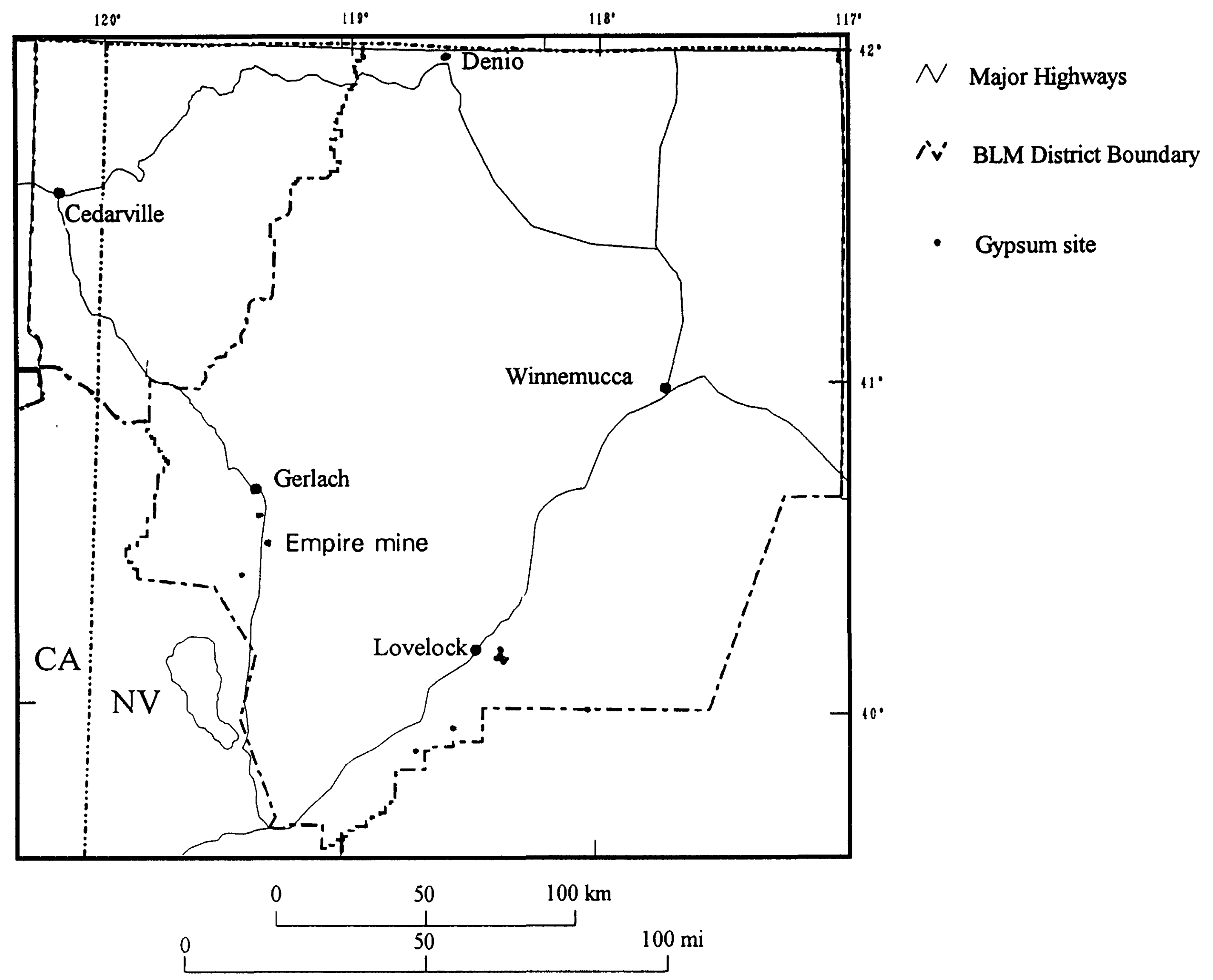

Figure 7. Location of known mines, prospects, and occurrences of gypsum in the WSRA. Information from MRDS and MILS databases.

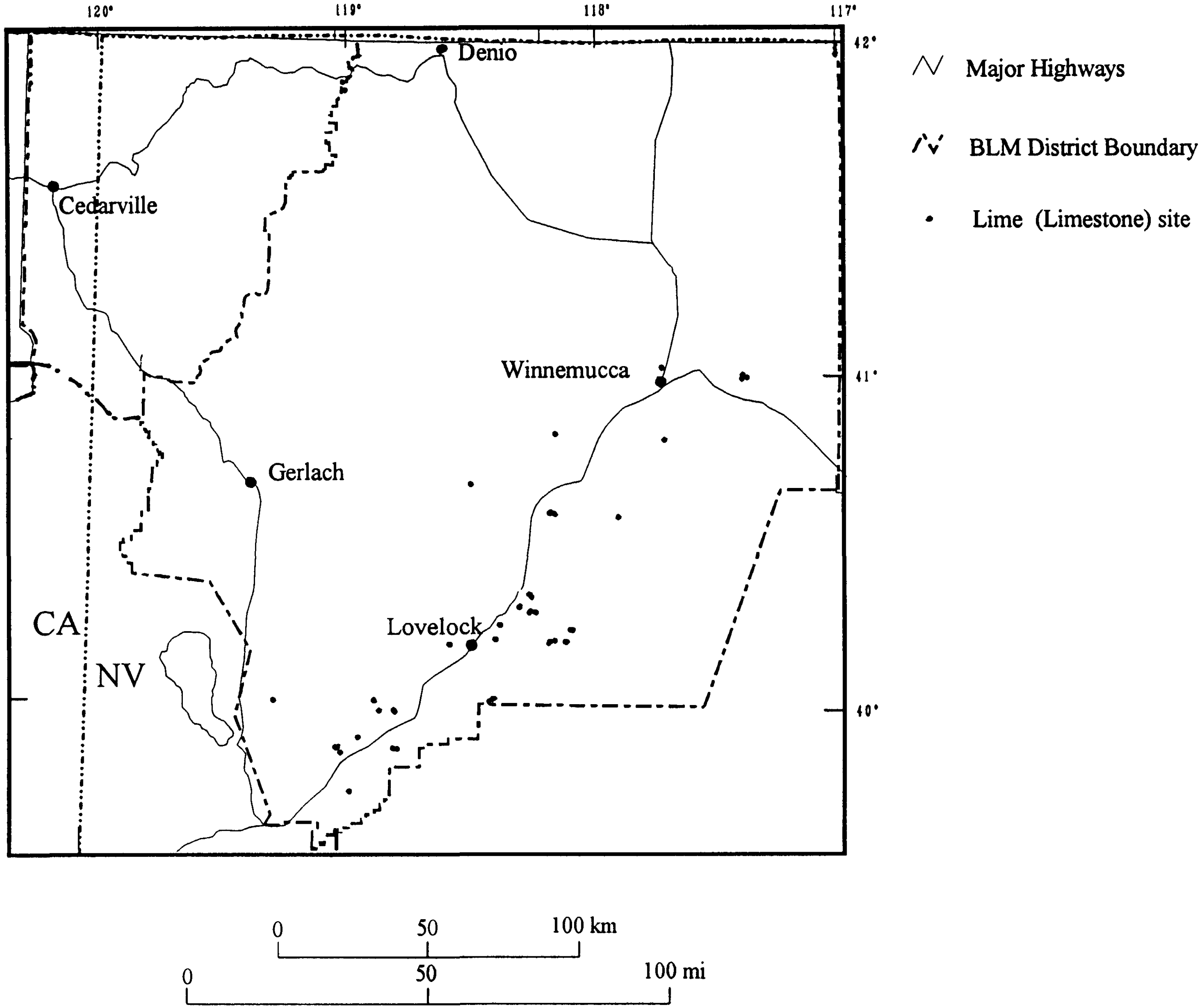

Figure 8. Location of known mines, prospects, and occurrences of limestone (lime) in the WSRA. Information from MRDS and MILS databases.

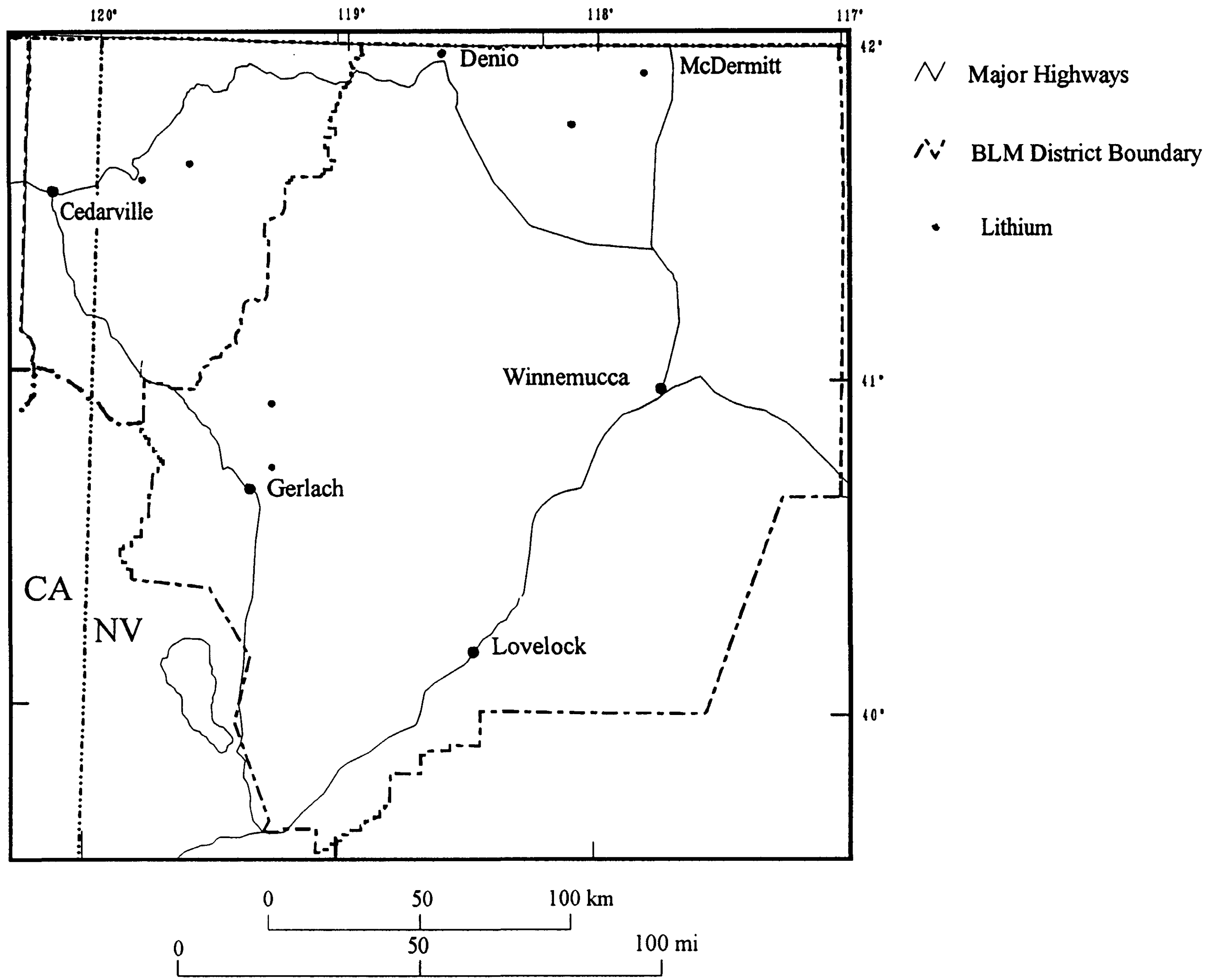

Figure 9. Location of known mines, prospects, and occurrences of lithium in the WSRA. Information from MRDS and MILS databases.

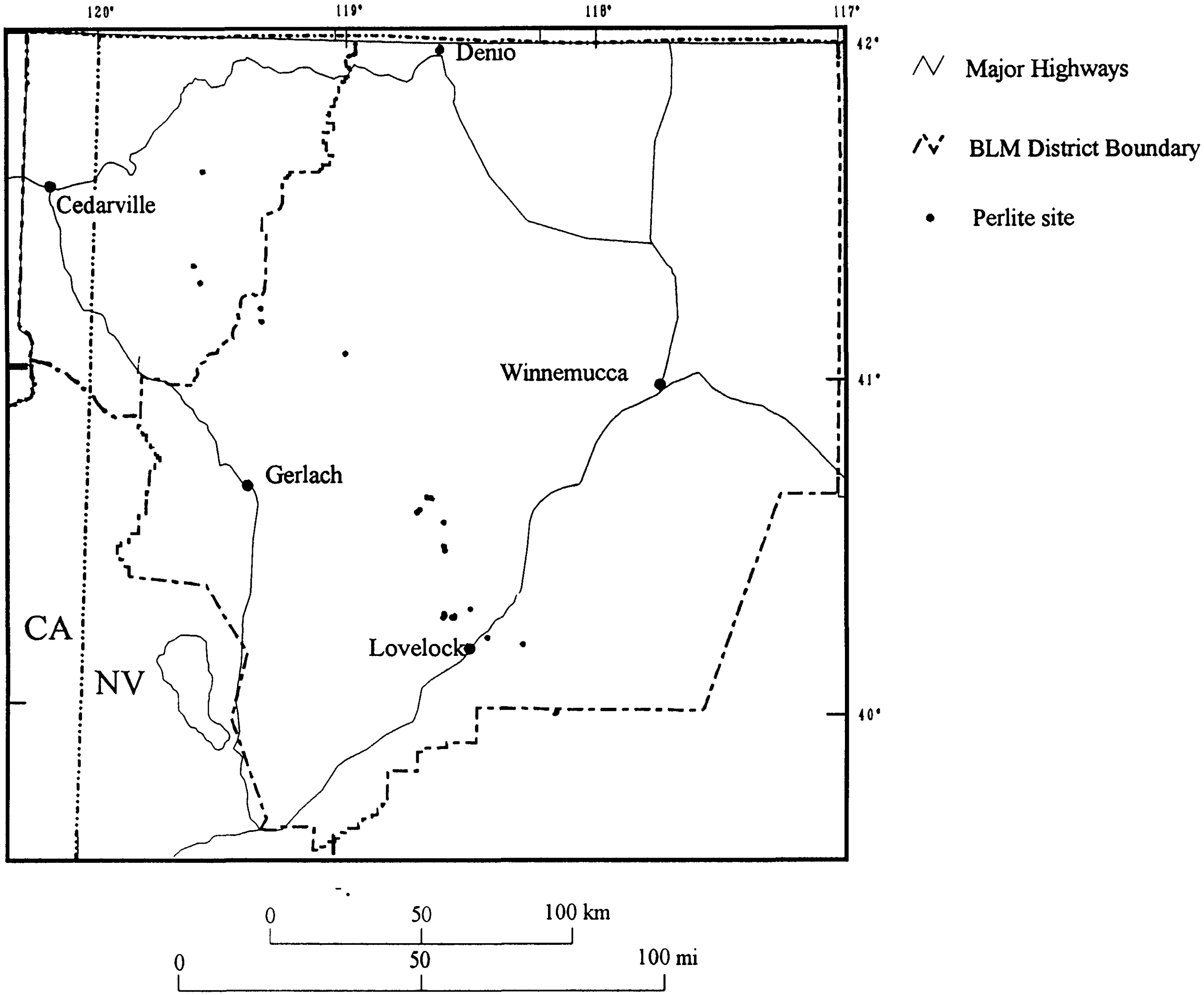

Figure 10. Location of known mines, prospects, and occurrences of perlite in the WSRA. Information from MRDS and MILS databases.

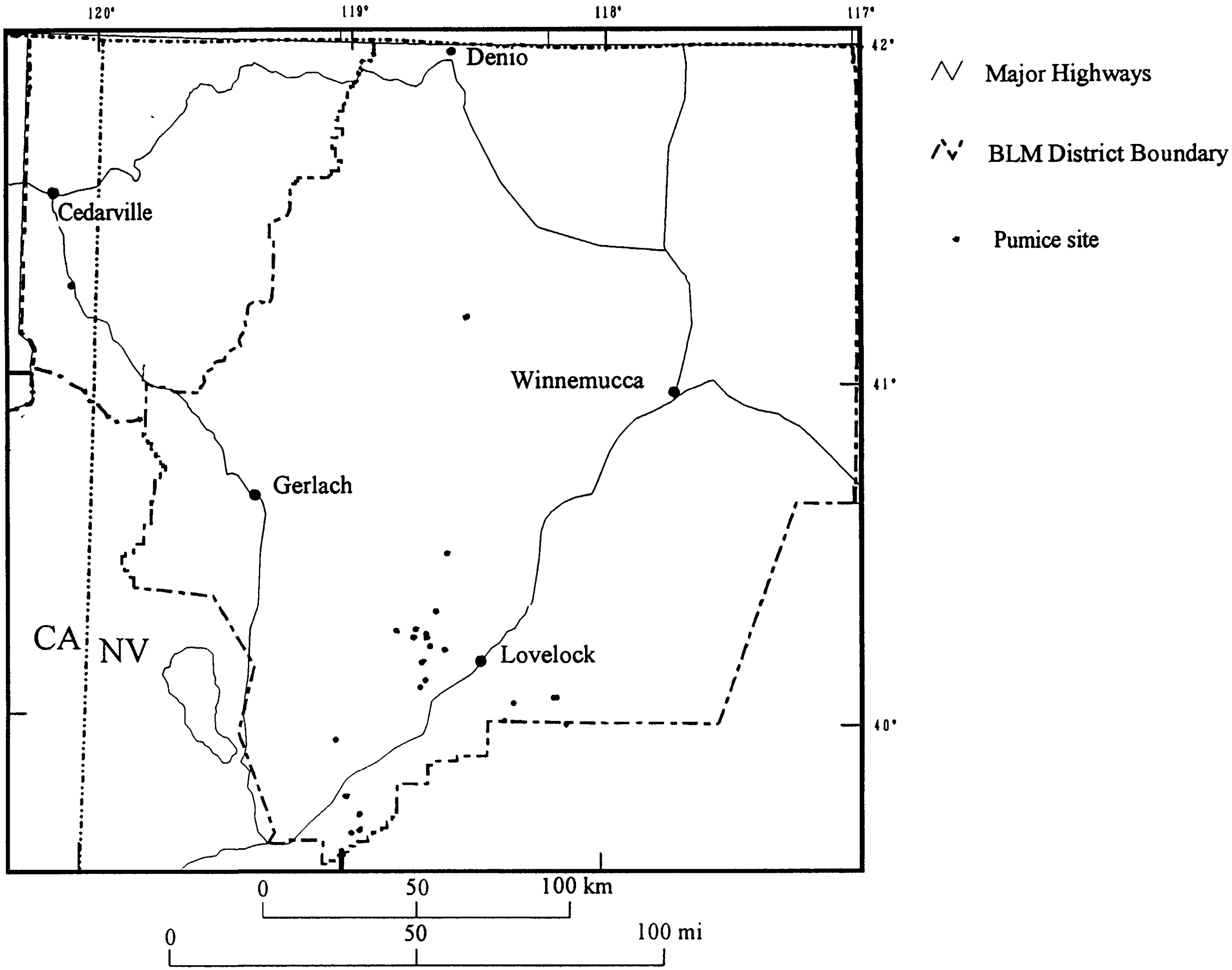

Figure 11. Location of known mines, prospects, and occurrences of pumice in the WSRA. Information from MRDS and MILS databases.

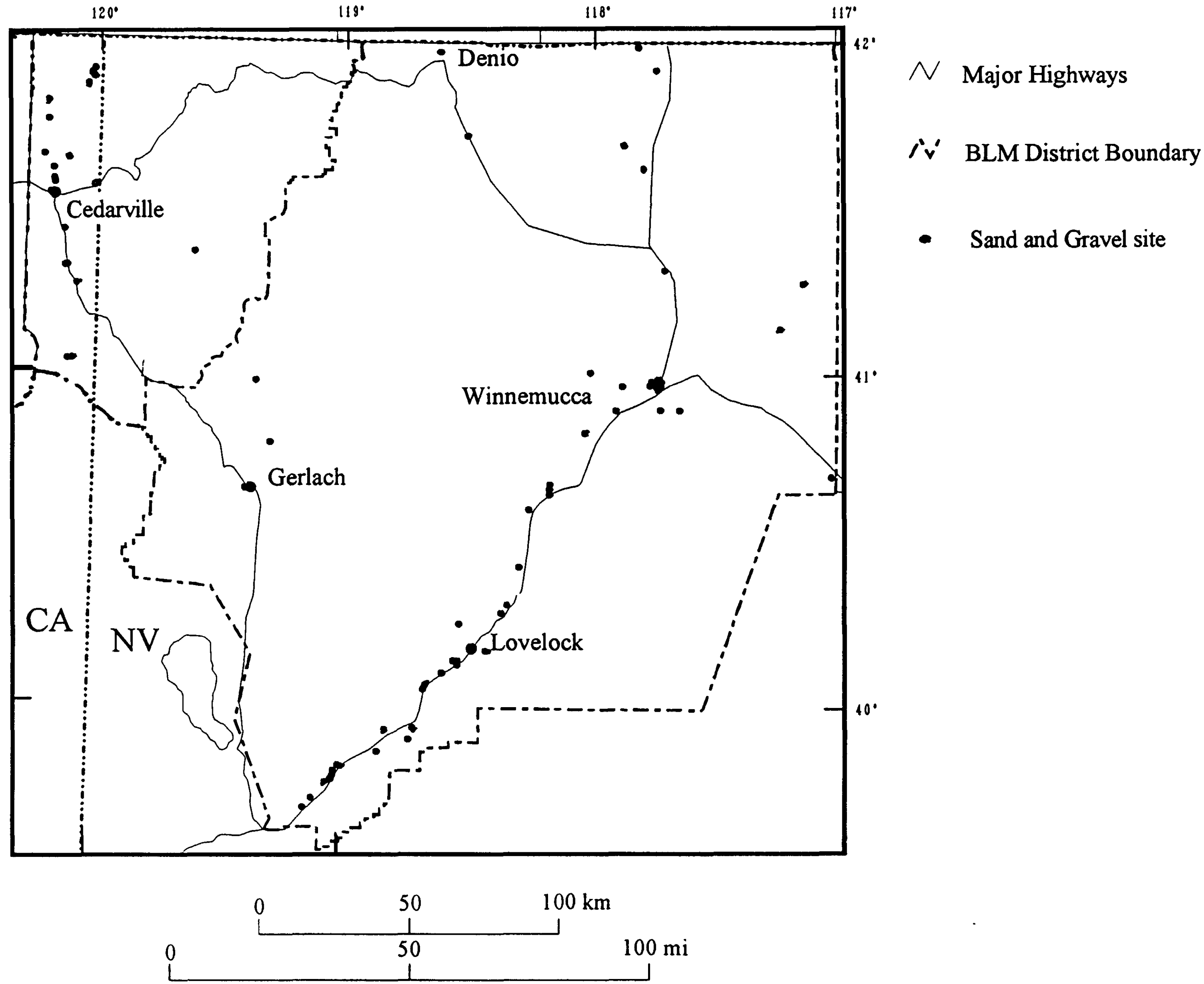

Figure 12. Location of known mines, prospects, and occurrences of sand and gravel (aggregate) in the WSRA. Information from MRDS and MILS databases.

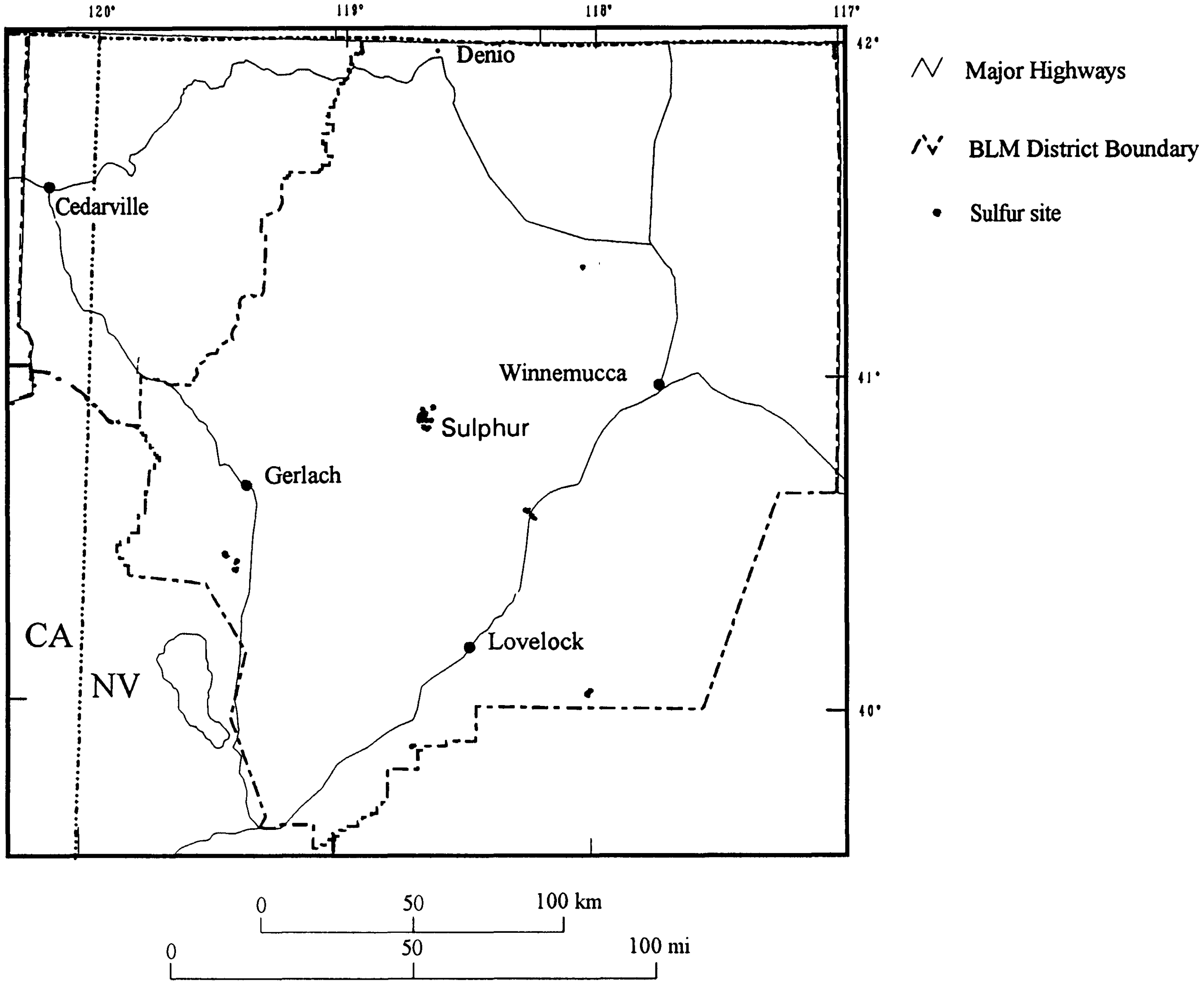

Figure 13. Location of known mines, prospects, and occurrences of sulfur in the WSRA. Information from MRDS and MILS databases.

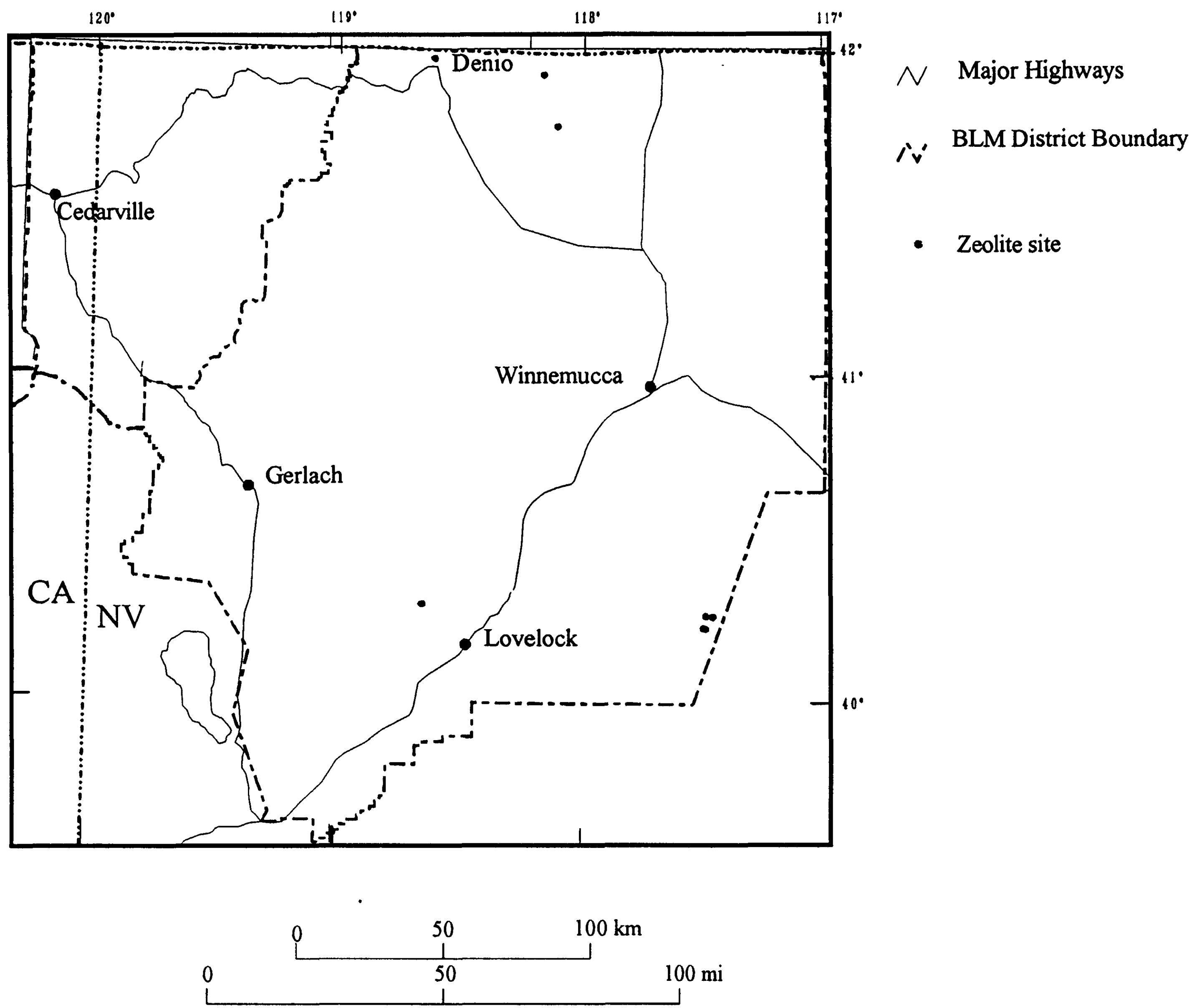

Figure 14. Location of known mines, prospects, and occurrences of zeolites in the WSRA. Information from MRDS and MILS databases.