Cover: Prominent granite outcrops at Lone Mountain, north-northwest of Elko, Nevada, are part of the Nannies Peak intrusion.
Modal Composition and Age of Intrusions in North-Central and Northeast Nevada

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1. Intrusions of north-central and northeast Nevada [see separate file]
Introduction

Data presented in this report characterize igneous intrusions of north-central and northeast Nevada and were compiled as part of the Metallogeny of the Great Basin project conducted by the U.S. Geological Survey (USGS) between 2001 and 2007. The compilation pertains to the area bounded by lats 38.5° and 42° N., long 118.5° W., and the Nevada-Utah border (fig. 1). The area contains numerous large plutons and smaller stocks but also contains equally numerous smaller, shallowly emplaced intrusions, including dikes, sills, and endogenous dome complexes. Igneous intrusions (hereafter, intrusions) of multiple ages are major constituents of the geologic framework of north-central and northeast Nevada (Stewart and Carlson, 1978). Mesozoic and Cenozoic intrusions are particularly numerous and considered to be related to subduction along the west edge of the North American plate during this time.

Henry and Ressel (2000) and Ressel and others (2000) have highlighted the association between magmatism and ore deposits along the Carlin trend. Similarly, Theodore (2000) has demonstrated the association between intrusions and ore deposits in the Battle Mountain area. Decades of geologic investigations in north-central and northeast Nevada (hereafter, the study area) demonstrate that most hydrothermal ore deposits are spatially, and probably temporally and genetically, associated with intrusions. Because of these associations, studies of many individual intrusions have been conducted, including those by a large number of Master’s and Doctoral thesis students (particularly University of Nevada at Reno students and associated faculty), economic geologists working on behalf of exploration and mining companies, and USGS earth scientists. Although the volume of study area intrusions is large and many are associated with ore deposits, no synthesis of available data that characterize these rocks has been assembled.

Compilations that have been produced for intrusions in Nevada pertain to relatively restricted geographic areas and (or) do not include the broad array of data that would best aid interpretation of these rocks. For example, Smith and others (1971) presented potassium-argon geochronologic and basic petrographic data for a limited number of intrusions in north-central Nevada. Similarly, Silberman and McKee (1971) presented potassium-argon geochronologic data for a significant number of central Nevada intrusions. More recently, Mortensen and others (2000) presented uranium-lead geochronology for a small number of central Nevada intrusions. Sloan and others (2003) released a national geochronologic database that contains age determinations made prior to 1991 for rocks of Nevada. Finally, C.D. Henry (Nevada Bureau of Mines and Geology, written commun., 2006) has assembled geochronologic data for igneous rocks of Nevada produced subsequent to completion of the Sloan and others (2003) compilation. Consequently, although age data for igneous rocks of Nevada have been compiled, data pertaining to other features of these rocks have not been systematically synthesized. Maldonado and others (1988) compiled the distribution and some basic characteristics of intrusions throughout Nevada. Lee (1984), John (1983, 1987, and 1992), John and others (1994), and Ressel (2005) have compiled data that partially characterize intrusions in some parts of the study area. This report documents the first phase of an effort to compile a robust database for study area intrusions; in this initial phase, modal composition and age data are synthesized. In the next phase, geochemical data available for these rocks will be compiled. The ultimate goal is to compile data as a basis for an evaluation of the time-space-compositional evolution of Mesozoic and Cenozoic magmatism in the study area and identification of genetic associations between magmatism and mineralizing processes in this region.

Acknowledgments

We would like to thank the staff of the USGS Denver library, who were critical to the success of this compilation. In particular, the library staff used the interlibrary loan process to obtain many of the geologic reports on which this compilation...
Figure 1. Index map showing approximate distributions of intrusive rocks in north-central and northeast Nevada. Thin purple line outlines the study area. Intrusions indicated by red polygons.
is based. Financial support provided by the USGS to Crafford enabled compilation of the digital geologic map. We would like to gratefully acknowledge technical reviews by S.D. Ludington and J.L. Doebrich that helped improve this report.

Data Sources and Compilation Methods

Many geologic investigations have demonstrated that study area intrusions are principally of three ages, Jurassic, Cretaceous, and Eocene. In the western part of the study area, a number of intrusions are thought to be of Triassic age (Johnson, 1977). Christiansen and Yeats (1992) documented southward-sweeping Eocene magmatism that began in British Columbia at about 54 Ma and extended into Nevada by 43 Ma. Eocene intrusions are voluminous in the study area and may be related to foundering of the Farallon slab beneath western North America (Humphreys, 1995). Several small, shallowly emplaced Miocene intrusions have been delineated in various parts of the study area (plate 1). This report does not contain data for Paleozoic intrusions, which are principally of very mafic composition and are likely parts of detached, allochthonous thrust sheets.

The geologic base for this database is derived from Crafford’s (in press) new 1:250,000-scale compilation of Nevada geology, which uses a projected North America UTM coordinate system (zone 11N) and the North American Datum of 1927 (NAD27). The new map was created using the Nevada Bureau of Mines and Geology county reports and accompanying 1:250,000-scale geologic maps and the 1:500,000-scale geologic map of Nevada (Stewart and Carlson, 1978) as primary sources. County map polygon attributes were updated to reflect new regional geologic interpretations, to reconcile county boundary issues, and to reflect new information. Only about 10 percent of the actual polygon shapes were revised. Geologic mapping, usually at larger scale, conducted subsequent to completion of the county maps has shown that some intrusions portrayed on the county maps are composite. Using more recent mapping, internal contacts were added within composite plutons in order to delineate separate intrusions. The resulting compilation served as the starting point for the work described here. Geochronologic and modal composition (hereafter, composition) information was compiled for each intrusion depicted on the new map. Map unit labels used to categorize intrusions of the study area have been further refined and updated from those used on the new statewide map (Crafford, in press) in order to reflect geochronologic and composition information compiled as part of this study.

We inferred that the best geochronologic and composition data for study area intrusions could be gleaned from detailed (1:62,500 and larger scale) geologic maps (in preference to publications that lack associated geologic maps) and accompanying descriptions of map units. The new digital geologic map (Crafford, in press) was used to identify the spatial limits of study area intrusions. This location information was used as input to the search engine for the USGS National Cooperative Geologic Mapping Program catalog of geologic mapping (http://ngmdb.usgs.gov/). Results of these searches identified the geologic maps that portray each study area intrusion. Copies of original data source materials (subsequently referred to as sources), including published maps and maps contained in Master’s and Doctoral theses, were obtained and used to compile geochronologic and composition data for each study area intrusion. In rare cases, quite generalized data included on the county maps and in their associated reports were compiled because these are the only data available for particular intrusions. Data for about 300 intrusions from about 200 sources were identified and are incorporated in the accompanying database. We believe that this process has resulted in compilation of the best available geochronologic and composition data for study area intrusions.

The list of citations below identifies the sources that were used to compile age and composition data for study area intrusions. Full citations for each of these publications are provided in the “References Cited” section of this report. Numbers beside each citation below correspond to entries in the “source” columns included on the spreadsheet and (or) in the shapefile (in_nam_src, age_src, comp_src, geol_refs).

3. Vikre (1985a)
4. Hotz and Willden (1964)
5. Erickson and Marsh (1974a)
6. Erickson and Marsh (1974b)
7. Gilluly (1967)
9. Willden (1964)
11. Coats (1971)
12. Decker (1962)
13. Coats and Greene (1984a)
14. Coats and Greene (1984b)
15. Coats and Greene (1984c)
16. Bushnell (1967)
17. Coats and others (1977)
18. Coash (1967)
19. Higgs (1960)
22. Gibbons (1973)
23. Lee and Van Loenen (1971)
25. Evans and Ketner (1971)
26. Ketner (1973)
27. Ketner and Smith (1963)
29. Glick (1987)
30. Day and others (1987)
32. Hope (1972)
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33. Messin (1973)
34. Miller and others (1987)
35. Sayyah (1965)
36. O’Neill (1968)
37. Snow (1964)
39. Barnes and others (2001)
40. Evans (1974a)
41. Evans (1974b)
42. Peters (2003)
43. Shawe and others (1962)
44. Muffler (1964)
45. Gilluly and others (1965)
46. Roberts and others (1967)
47. Haworth (1979)
48. Stewart and McKee (1969)
49. McKee (1968a)
50. Nolan (1962)
51. Hose and others (1976)
52. Moores and others (1968)
54. Whitebread (1969)
55. McDonald (1989)
56. Humphrey (1960)
57. Morabbi (1980)
58. Fritz (1968)
59. Boyden (1972)
60. Sayeed (1973)
61. Brokaw and others (1973)
62. Heidrick (1965)
63. Drewes (1967)
64. Lee and others (1999a)
65. Lee and others (1999b)
66. Miller and others (1999)
67. Miller and others (1994)
68. Miller and others (1995)
69. McKee (1976a)
70. Kleinhamp and Zioni (1984)
71. Lumsden (1964)
72. Coles (1989)
73. Shawe (1995)
74. Shawe (1999)
75. Silberling and John (1989)
76. Bonham (1970)
77. Silberling (1959)
78. Shawe (2002)
80. Means (1962)
81. McKee (1968b)
82. Speed and McKee (1976)
83. Pullman (1983)
85. Tingley (1986)
86. Ekren and Byers (1986a)
87. Taylor (1982)
89. Ekren and Byers (1986b)
90. Hudson and others (2000)
91. Ekren and Byers (1985a)
92. Willden and Speed (1974)
94. John and Silberling (1994)
95. Bryan (1972)
96. Henry (1996)
97. Barrows (1971)
98. Wallace and others (1969a)
100. Nevada Bureau of Mines and Desert Research Institute (1963)
102. Doebrich (1994)
103. Clement (1961)
105. Gilluly and Masursky (1965)
107. McKe and Stewart (1969)
108. Stewart and McKee (1968)
109. Stewart and McKee (1977)
110. McBee (1976b)
111. Welch and others (1981)
112. Whitebread (1994)
113. Perry (1985)
114. Whitebread and Sorensen (1980)
115. Johnson (1977)
117. Silberling and Wallace (1967)
118. Decker (1972)
119. Wallace and others (1969b)
120. Lovejoy (1959)
121. Neff (1969)
122. Armstrong and Suppe (1973)
123. Armstrong and others (1976)
124. Best and others (1974)
125. Carlson and others (1975)
126. Coats and McKee (1972)
127. Coats and others (1965)
128. Damon (1965)
129. Edwards and McLaughlin (1972)
130. Elison and others (1990)
131. Erickson and others (1978)
132. Thole and Prihar (1998)
133. Evernden and Kistler (1970)
134. Garside and others (1981)
135. Gilluly (1965)
136. Groff and others (1997)
137. Armstrong (1964)
138. Armstrong (1966)
139. Armstrong (1970a)
140. Armstrong (1970b)
141. John and Robinson (1989)
143. Hitchborn and others (1996)
Information for some intrusions was incomplete or may have been misleading or incorrect, and (or) we may have incorrectly interpreted and compiled data presented in the sources, any of which could cause inaccuracies in the database. An effort has been made to minimize such inaccuracies.

Data Structure

Data are compiled in spreadsheet form using Microsoft Excel and can be accessed using software compatible with .xls files. The database release (file, IntrusionsNENV.xls) includes two worksheets that are accessed using tabs arrayed along the base of the spreadsheet display. The tab labeled “IntrNENVpolys” is the primary data compilation. A copy of the compilation was sorted alphabetically, based on intrusion name, and then filtered to yield a unique, single-row listing for each intrusion. The resulting derivative database, accessed using the tab labeled “IntrSorted,” succinctly presents the composition and age of each intrusion. The database release also includes tab-delimited, text file versions of the primary data compilation (file, IntrNENVpolys.txt) and the sorted, derivative version (file, IntrSorted.txt). Data contained in the primary compilation are joined with an ArcGIS shapefile of the study area intrusions to create an attributed shapefile (Intrusions_polyNENV.shp). The attributed shapefile documents the distribution of study area intrusions and can be used in conjunction with ArcGIS to display their associated composition and age information. Subsequent references to spreadsheet and shapefile refer to these two files. Metadata for the ArcGIS files are embedded in the geospatial database and are also contained in a freestanding text file (file, Metadata.txt).

Data Fields

Data fields presented and described below represent those considered most important to establishing a foundation for compilation of geochemical data for study area intrusions. Data for each of these fields constitute a column, or set of related columns, in the spreadsheet (IntrusionsNENV.xls) and shapefile (Intrusions_polyNENV.shp). Data in these columns can be sorted, queried, and interpreted to address questions concerning basic characteristics of study area intrusions. Specifics of these data fields are also described in the metadata that accompanies the shapefile.

**intrusion_name**

A unique geographic name was defined for each intrusion; these names are compiled in the “intrusion_name”
column. Sources that were used to define intrusion ages and compositions were also used to help define geographic names. Intrusion names identified in the sources were adopted for the compilation. For some study area intrusions, no geographic names had been previously defined. In these cases, a nearby named geographic feature was adopted and assigned as the intrusion name. Many intrusions are depicted as a single polygon in the shapefile to which a unique geographic intrusion name is assigned. In many cases, intrusions consist of multiple polygons that, based on plausible geologic reasoning, are probably parts of a single intrusion that is differentially exposed as isolated masses. In these cases, the same geographic intrusion name was assigned to a group of spatially related intrusion polygons. Assigned geographic intrusion names do not constitute formal stratigraphic nomenclature. However, for intrusions with either formal or informal stratigraphic nomenclature, and to the extent that the sources identified these names, geographic names included in this compilation are in accord with established stratigraphic nomenclature.

**in_nam_src**

Sources that explicitly identified geographic names for intrusions are identified in the “in_nam_src” column on the spreadsheet. Blank cells in this column indicate intrusions for which sources did not identify a geographic name for the associated intrusion; in these instances, we assigned the name of a nearby named geographic feature as the intrusion name.

**age**

The ages of study area intrusions have been of keen interest and a large number of age determinations have been made. The database column titled “age” contains ages of study area intrusions compiled from sources cited in “age_src.” Numeric entries are geochronologic data, in millions of years. In cases for which numeric data are lacking or inconclusive, the best available chronologic age data are compiled. Multiple geochronologic age determinations have been obtained for some intrusions. In these cases, an age range, based on all identified age determinations, is presented. Presenting ages rounded to the nearest million years is suitable for our compilation; however, full analytical precision and accuracy data can be obtained by consulting the source of compiled age data.

**age_src**

Radiometric age data for samples of study area intrusions were compiled from primary data sources. Principal sources of geochronologic data for these intrusions include Smith and others (1971), Silberman and McKee (1971), and Mortensen and others (2000). These and sources compiled by Sloan and others (2003) and C.D. Henry (Nevada Bureau of Mines and Geology, unpublished data, 2006) are tabulated in the “age_src” database column.

**best_age**

As described above, multiple age determinations are available for some intrusions. In the column titled “best_age” we compile, based on geologic reasoning and the reliability of the isotopic systems used in various age determinations, what we consider to be the best approximate age of each intrusion. Ages of intrusions with single age determinations are simply replicated in this column. Entries in the “best_age” column, in millions of years, depict the time-space evolution of magmatism in the study area. In most cases, the age value in the “best_age” column is derived from the range of values in the “age” column. However, when other geologic reasoning suggests a different or more specific “best_age” (for example, Cove, Hoodoo, Stony Basin central), the user should consider the “best_age” data, not the “age” data, as the interpreted age of the intrusion. Blank entries in the “best_age” column indicate that the “age” column contains no numeric age data and so no “best_age” estimate can be made.

**modal_composition**

Intrusive rock modal compositions are classified using their relative proportions of quartz, alkali feldspars, and plagioclase and nomenclature defined by Streckeisen (1973). The most informative sources presented relative proportions of the feldspars and quartz in text accompanying geologic maps; this information was used to establish composition (or composition range) names, compiled in the “modal_composition” column, for study area intrusions. Intrusions for which no modal composition information is available are simply classified as “Intrusive rock.” Many of the sources for our compilation predate the classification recommendations of Streckeisen (1973); most of these used the classification of Johannsen (1939) to define intrusion compositions. To the extent possible, and using whatever ancillary data were available, intrusion compositions were converted from the nomenclature of Johannsen (1939) to that of Streckeisen (1973). Most of these transformations were simple and obvious. However, the two systems use the term quartz monzonite to define significantly different rocks. Most of the composition field called quartz monzonite by Johannsen (1939) is referred to as monzogranite in the Streckeisen (1973) system. Not all sources defined which of the two classification schemes was used to categorize intrusion compositions, so some ambiguity persists. Compositions were recast to Streckeisen (1973) nomenclature in cases for which sufficient data were available to achieve this with some confidence.

Many of the study area intrusions are shallowly emplaced and (or) subvolcanic bodies. As such, their grain size precludes petrographic modal analysis and classification using the Streckeisen (1973) system. These rocks are instead treated
as volcanic rocks and their nomenclature established using chemical analyses and the classification grid of Le Bas and others (1986).

**comp_src**

Modal composition names for samples of study area intrusions were compiled, as described above, from primary data sources. Sources used to compile information in the “modal_composition” column are enumerated in the column titled “comp_src.”

**age_code**

To develop the first part (age) of a geologic map unit “geologicfm” for each polygon, a simplified geologic period “age_code” was first derived by comparing information in the “best_age” or “age” columns to age designations on a standard geologic time scale. Pliocene-Miocene, Miocene, Miocene-Oligocene, Oligocene-Eocene, and Tertiary intrusions were assigned a “T” “age_code.” Cretaceous intrusions were assigned a “K” “age_code.” Jurassic intrusions were assigned a “J” “age_code.” Triassic and Triassic-Perman intrusions were assigned a “TR” “age_code.” Tertiary-Cretaceous intrusions, Tertiary-Jurassic intrusions, Cretaceous-Jurassic intrusions, and intrusions with an unknown or poorly known age were assigned a “TJ” “age_code.” The age associated with each “age_code” is indicated on the explanation of the geologic map and in the shapefile metadata.

**comp_code**

To develop the second part (composition) of a geologic map unit “geologicfm” for each polygon, a simplified composition code (“comp_code”) was derived for each polygon from information in the “modal_composition” column. The broad array of compositions identified in the “modal_composition” column was binned to provide a reduced number of geologic map units. Felsic phaneritic intrusion compositions (“comp_code” = fi) include aplite, granite, granite-granodiorite, granite-quartz monzonite, granodiorite, granodiorite-dacite, granodiorite-monzogranite, granodiorite-quartz diorite, granodiorite-quartz monzodiorite, leucogranite, leucogranoiodiorite, monzogranite, monzogranite (aplitic), monzogranite-granodiorite, monzogranite-quartz monzonite, monzogranite-syenogranite, pegmatite and aplite, tonalite, and tonalite-monzogranite; phaneritic intermediate intrusion compositions (“comp_code” = ii) include basalt-dacite-diorite, quartz diorite, quartz monzodiorite, quartz monzodiorite-granodiorite, quartz monzodiorite-quartz monzonite, quartz monzonite, and quartz monzonite-monzogranite; phaneritic mafic intrusion compositions (“comp_code” = mi) include diabase, diorite, diorite-quartz monzonite, gabbroic rocks, metadiorite, monzodiorite, monzogabbro, monzonite, monzonite-quartz monzonite, and monzonite-rhyolite. Jurassic intrusive rocks (mostly gabbro) of the Humboldt complex are assigned a “comp_code” = gb. All phaneritic intrusions whose compositions are unknown or poorly known (diorite-granite, granitic rock, or intrusive rock) are assigned a “comp_code” = i. Shallow intrusions that include some aphanitic groundmass were binned as rhyolite (including quartz porphyry, quartz-feldspar porphyry, and rhyolite) (“comp_code” = ri), rhyolite-dacite (“comp_code” = rhdi), dacite (including dacite and quartz latite) (“comp_code” = di), andesite (“comp_code” = ai). The rock type associated with each code is indicated on the explanation of the geologic map and in the shapefile metadata.

**geologicfm**

The final step in defining the age and composition of rock associated with each intrusion polygon resulted in definition of a “geologicfm”. Each “geologicfm” was derived by combining the “age_code” and “comp_code” values for each polygon to create a geologic map unit “geologicfm” for portrayal on the geologic map. The explanation of each “geologicfm” is indicated on the explanation of the geologic map and in the shapefile metadata.

**geol_refs**

In accord with improved geologic knowledge, boundaries of some intrusion polygons, as compiled in the database described here, were modified from those depicted on the source county geologic map. Entries in the “geol_refs” column identify the source (keyed to the numbered source list presented in the “Data Sources and Compilation Methods” section of this report) from which improved polygon boundary information was derived.

**county**

In order to aid location of intrusion polygons and to enable some sorting processes, the name of the Nevada county or counties that contains each intrusion polygon is compiled in the “county” column.

**shape_leng**

In order to aid an analysis of intrusion size, the perimeter (in meters) of each intrusion polygon is compiled in the “shape_leng” column.
As an additional aid to analysis of intrusion size, the area (in square meters) of each intrusion polygon is compiled in the "shape_area" column.

References Cited


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