Explanatory Notes for

A 1:250,000 ScaleNevada State Digital Geologic Map
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and

A Digital Conodont Database of Nevada
by Anita G. Harris and Elizabeth Crafford

TABLE OF CONTENTS

INTRODUCTION

The purpose of the Nevada State Digital Geologic Map is to provide an integrated set of digital geologic information that can be used for regional geologic analysis. Two components of this map represent new information that has not been published in this form before. The new geology layer was created by merging individual digital Nevada county geologic maps (Hess and Johnson, 1997), published at a scale of 1:250,000 into a single file, creating a new regional interpretation to unify all the different county rock units, and then making appropriate edits and modifications to that file to reflect additional geologic information and more current geologic interpretations. All possible sources of information were NOT utilized in the scope of this project, but rather the goal was to create a consistent statewide 1:250,000-scale map that would facilitate regional geologic interpretation. Secondly, a new database of conodont biostratigraphic data compiled and analyzed by Anita Harris is also incorporated into the map. Other previously published data layers used in this map include mineral deposit locations, oil well locations, and cartographic layers that includes county boundaries, roads, towns, cities, rivers, water bodies, Township, Range and Section grids, quadrangle grids, and topography. A summary of these components is given below, and complete descriptions of each layer are provided in the digital metadata.

CREATING THE DIGITAL MAP

The necessary first step to create the Nevada State Digital Geologic Map was creation of digital polygon and line coverages from the original published county geologic maps. This was done by the Nevada Bureau of Mines and Geology in 1996 (Hess and Johnson, 1997). Their careful creation of over 34,000 polygons of geology made possible the next step of integrating together the geologic information from the different maps into a new unified explanation. The 16 different geologic maps were created over a time span of more than 20 years by different people using different geologic standards, but all at a scale of 1:250,000. Remarkably, in spite of the large number of contributors over such a long time, the locational accuracy of the basic geologic polygon boundaries are good to excellent, with only a few areas needing significant modification. Interpretations of the units, however, vary significantly, and some required substantial modification on the basis of newer information, ideas, and interpretations. A new regional interpretation of the geology of Nevada is presented with this map and applied to the polygons from the county maps. The interpretation draws on the work of many, including the original State Geologic Map (Stewart and Carlson, 1978; Stewart, 1980). This new regional interpretation resulted in combining the 1,016 units used on the county maps into just over 100 statewide units. In addition to geology polygons, boundaries of the polygons with their attributes, and fault traces were combined from the multiple county maps into individual statewide layers, but were not edited for this project. The new user of the map will benefit from studying the accompanying legend presented as a separate document "NevadaDigitalGeologicMapLegend.pdf".

DIGITAL CAVEATS

The benefits of a digital map are many. The user can easily choose layers to turn on or off, modify those layers to suit their needs, and display or print information of particular interest at a particular scale. A digital map also introduces important caveats and responsibilities of which the user must be aware. The only layer of this map that has been spatially edited (the boundaries of the polygons themselves have been altered in some cases, and new polygons have been created) is the geology polygon layer. The other two geology layers, the faults layer, and the geologic boundaries layers have *not* been edited yet to match the new geology polygon boundary layers. Therefore, in places where the geology has been edited, the boundaries of the polygons will *no longer match* the lines associated with the faults layer or the boundaries layer. Additionally, there are cases where one existing polygon was split into numerous pieces to improve either the location or interpretive accuracy of the map, with the different pieces being assigned to different units. This procedure results in a more accurate display of the geology, but also introduces spurious boundaries that have no geologic meaning. The boundaries are transparent, but the user needs to be aware that an area of a single geologic unit may be composed of several adjoining polygons. Hopefully a future release of this map will be able to address these challenging issues. These problems, however, only apply to approximately 10 percent of the polygons on the map, and thus most boundary and fault lines still agree with the geology polygons, and should not affect general use of the map.

When combining layers of data from different sources, such as biostratigraphic or radiometric data with the geologic data, inherent variables mean that raw data from the two layers will not always match as expected. Location inaccuracies in point samples, map-scale inaccuracies of geologic polygons and many other factors make this a significant issue. For this first release of the digital map, geologic and biostratigraphic layers are not all reconciled -- in other words, for example, some Devonian conodonts plot in alluvium adjacent to the Devonian rock unit from which they were sampled, not within the boundaries of the polygon as expected. With continued support, resolution of these discrepancies is a primary goal for future releases of the map, so that data will be fully integrated and benefits of a GIS system can be utilized to effectively analyze the data. Attributes in both the geology and biostratigraphy layers attempt to document the discrepancies with the future hope of resolving them.

A benefit of the digital map is that a great variety of attributes can be attached to any spatial object. This means that information about a specific polygon, such as boundary edits or value changes can easily be attached to that feature. The user should take advantage of the many annotations included as attributes to the individual polygons explaining reference details, discrepancies, and unsolved problems for that particular polygon when interpreting the geology.

COMPONENTS OF THE DIGITAL MAP

To provide context for the geologic information, additional layers of geographic and geologic information are also portrayed on the map. A brief description of each of the maps components is provided below under a heading that matches the folder on the CD that contains the data. A complete listing of the files in each folder is provided in the accompanying readme.pdf document. Additional details including descriptions of all the attributes for each data set are provided in the metadata accompanying each data file. To access the digital map and metadata, the user needs ArcGIS 9.x software, and should open one of the NevadaStateDigitalGeologicMap.mxd files described in the “Read Me First.doc” included on the CD. The map is accessed through ArcMap, and the xml metadata files can be viewed through ArcCatalog.

Biostratigraphy

The biostratigraphic information presented here consists of 2617 conodont sample locations from A.G. Harris, U.S.G.S., emeritus in a shape file called ConodontSamples.shp. They represent samples collected by many individuals over many years, and examined by Anita Harris. Sample locations were provided by Harris and except for a handful have not been verified for this publication. Conodont data are displayed in seventeen different layers in the project. Fifteen layers have data broken out by sample age or age range, and colored by CAImin value. One layer shows samples taken from the subsurface such as drill holes or underground mine workings. Another single layer shows all of the conodonts, not differentiated by time, colored by their CAImin value. Each age or age range has a different color rim on the symbol or a different shape symbol. The CAI color scale used is intended to mimic the actual conodont color.

Cities

The cities_p.shp shape file provided by the Nevada Bureau of Mines and Geology is a layer of 101 point locations for Nevada cities and towns at 1,000,000 scale.

Contours

The CTOUR2.shp shape file is a layer consisting of 150 meter, 2 arc second contours that were derived from the DLG map of Nevada, and created at the Nevada Bureau of Mines and Geology.

Counties

NevadaCounties.shp is a shape file of Nevada counties with the latest boundary locations updated. It was provided by the Nevada Department of Transportation.

Geology

Three different layers are used for the primary geologic information. The geology polygon file is a personal geodatabase, StatewideGeology.mdb that has attributes to describe each of the polygons used on the map. The geologic boundaries shape file (StatewideGeoBoundaries.shp) describes the characteristics of the boundaries of the geology polygons, such as whether they are known, inferred, faulted or concealed. The faults layer is the shape file StatewideFaults.shp and shows all the faults from the county maps, attributed by type of fault. The Faults and Boundaries layers have not been edited from their original digital version created by NBMG except to combine them into a single statewide file. This means that in places where the geology polygon boundaries have been edited, they will no longer match the fault or contact boundaries. This only affects about 10% of the geology polygons.

Lakes

Water Bodies taken from the 1:100,000 scale topographic maps were compiled into a shapefile, lake_100.shp by the Nevada Natural Heritage Program of the Department of Conservation and Natural Resources.

Public Land Survey

The Township and Range grid is shape file tr100grid.shp, and the section grid is shapefile plss100k.shp. These data sets were created by the U.S. Bureau of Land Management (BLM).

Quadrangles
Two quadrangle files are included. The 1:100,000 quadrangles shape file, nv_100kquads.shp, provided by the BLM, and 7.5' (1:24,000) quadrangle shape file, NVQDP.shp, provided by the U.S. Geological Survey.

Resources
Two different resource layers are included, Oil Wells and Mineral Deposits. The Oil Wells are plotted from a .dbf file provided by the Nevada Bureau of Mines and Geology, OFR04_1. It is current to June 2004. The mineral deposit information is taken from the USGS data file of MRDS deposits, mrds-fUS32.shp, now available online, updated from the 2000 version in 2005. Only those deposits that are designated as Model 19c, distal disseminated Ag-Au, or Model 26a Carbonate-hosted Au-Ag (Bliss, 1992; Cox and Singer, 1992) are currently displayed on the map, but the user can modify the display as needed to show any of the Nevada sites and multiple deposit models.

Rivers
The perennial and intermittent rivers and streams in Nevada are given in NevadaRivers.shp provided by the Nevada Bureau of Mines and Geology.

Roads
The primary roads in Nevada are shown in the roads layer, roads_A.shp provided by the Nevada Bureau of Mines and Geology.

SUMMARY OF REGIONAL GEOLOGIC INTERPRETATION AND UNIT DESIGNATIONS

A twofold challenge of creating this map was to combine the 1,000 plus County map geologic units into slightly more than 100 regional units while modifying the overall regional geologic interpretation from the original ideas in Stewart and Carlson (1978) to reflect new data and ideas. The value of a digital product is that it provides opportunity for trial and experimentation, allowing for the much iteration necessary to create an interpretation that is consistent with the data.

The user should study the new explanation for the map "NevadaDigitalGeologicMapLegend.pdf" and this summary to become familiar with the new regional interpretation. The rock unit designations for this new map are both traditional formal stratigraphic units, and other less formal designations that include assemblages and terranes. This method was chosen to reflect more clearly both the stratigraphic and tectonic history of these rocks. It is the combination of lithologic characteristics and structural characteristics, not one or the other, that define a unit as distinct from other groups of rocks. The third variable in regional interpretation is always the incompleteness of our understanding of the basic geologic data in many places, which contributes significantly to how they can be reasonably grouped.

Quaternary sediments and rocks reflect more inconsistency from county to county than rock units from most other age periods. Some counties differentiated older and younger alluvium and some did not, so two units were used but not always designated in each county (Qal, Qya). Sand dunes, playas and glacial moraines are also included as Quaternary units (Qs, Qpl, Qg). Only one

Quaternary volcanic unit, basalt flows, (Qb) is designated. Older sedimentary rocks include older alluvium (QToa), older gravels (QTg), hot spring deposits (QThs), and landslide deposits (QTls). The youngest volcanic rocks in the state include Late Tertiary or Early Quaternary basalt flows (QTb), andesite (QTa), rhyolite (QTr) and volcaniclastic sediments (QTs).

Most Tertiary rocks in Nevada are volcanic. Lacustrine, fluvial and tuffaceous sedimentary rocks were deposited in Tertiary basins scattered around the state. Tertiary intrusive rocks include felsic, rhyolitic and mafic varieties (Tfi, Tri, Tmi). The naming of the Tertiary volcanic and sedimentary rocks in this map follows closely the scheme used in Stewart and Carlson (1978) with a few consolidations supported by new information. There are three age groupings, from youngest to oldest, T3 (17-6 Ma), T2 (34-17 Ma), and T1 (43-34). There are five primary compositional and/or textural groupings for the volcanic and sedimentary rocks; sedimentary (Ts3, Ts2, Ts1), basaltic (Tb3, Tb2), andesitic (Ta3, Ta2, Ta1), tuffaceous (Tt3, Tt2, Tt1) and rhyolitic (Tr3, Tr2, Tr1). The distinction between the sedimentary units (Ts*x*) and the tuffaceous units (Tt*x*) is that Ts*x* represents sedimentary rocks that formed in a primary depositional environment (lake bed, fluvial, etc.) with some amount of tuff or tuffaceous sedimentary rock as part of the sequences, while the Tt*x* units are primarily volcanic in nature (welded or non-welded tuffs) and may have interlayered tuffaceous sedimentary horizons. In addition, a few Tertiary units (Tba, Tbg, Ths) are present that cross time and compositional boundaries, and they are designated separately. Mafic or felsic intrusive rocks of unknown age are mapped separately from Tertiary or Mesozoic intrusions (TJmi, TJfi).

Mesozoic intrusive, volcanic, sedimentary, and metamorphic rocks, including those associated with accreted terranes are all present in Nevada. These rocks formed in a variety of tectonic environments and depositional settings -- they reflect many diverse structural and tectonic histories. A few Triassic (TRfi), and numerous Jurassic (Jfi, Jgr, Jmi, Jgb) and Cretaceous (Kir, Kfi, Kmi) plutons of mafic, felsic and unknown compositions are scattered across the state, with a concentration near the Sierra Nevada associated with the Mesozoic arcs. Triassic (TRvm, TRkv), Jurassic (Jvr, Jvb) and unknown age (JTRv) volcanic rocks also range in composition from felsic to mafic and are spread across the central part of the state. Their tectonic settings and origins are not well understood, but they are likely related to the Triassic and Jurassic arc complexes, and possibly also to the accreted terranes.

Twelve different groupings of Mesozoic sedimentary and volcaniclastic rocks are recognized. They include clastic rocks and conglomerates that unconformably overlie older, folded and faulted rocks, distinct stratigraphic sequences in the southern, eastern and central parts of the state, and numerous different assemblages with distinct stratigraphic and structural histories that are juxtaposed in several different terranes along tectonic boundaries in the western half of the state. Mesozoic sedimentary rocks are difficult to classify because of their diversity of structural histories, depositional settings, and basements coupled with our incomplete knowledge of their relations to each other. Generally, they can be grouped into two categories -- those sequences that are deposited on a known basement, and those sequences that are strongly disrupted and their basement is either unknown or intimately deformed along with them as part of a larger terrane. In places where Mesozoic rocks have a complex deformation history, they are not grouped by formation, but rather they are grouped as either terranes or assemblages. Terranes are used in the classic sense for fault-bounded geologic entities of regional extent, each characterized by a geologic history that is different from the histories of contiguous terranes (Jones et al., 1983). Assemblage, an informal term, is used for a group of related rock units within a terrane, or for a unit (or units) that has a known basement, but is geographically isolated and lithologically and(or) structurally distinct from other coeval rocks. This can result in formation names being used across assemblages, but it provides a clearer picture of regional tectonic groupings of the rocks. This, in turn, provides the framework for understanding the overall tectonic evolution of these rocks and how their complex relations to one another have evolved over time. The groupings used here generally follow earlier terrane maps and discussions (Silberling et al., 1987; Silberling, 1991; Silberling et al., 1992) although several modifications have been made to reflect additional information. The groupings are displayed in the accompanying legend “NevadaDigitalGeologicMapLegend.pdf”.

Mesozoic rocks that are deposited on known basement include:

- the Triassic and Jurassic *Cratonal sequence* (Jas, JTRch, TRmt) in the eastern and southern parts of the state
- the Lower Triassic Candelaria Formation of the *Siliciclastic Overlap assemblage* (TRcl) best exposed south of Mina
- the Triassic and Jurassic *Humboldt assemblage* (JTRs, TRc) in a large area of Pershing, Churchill and Lander Counties
- the Triassic *Gold Range assemblage* (JTRgor) in Mineral and western Nye counties
- Jurassic and Cretaceous *Localized Clastic rocks* (TKcg, Kcg, Jcg) scattered in several places across the state

The disrupted rocks with unknown basement include those in:

- the Triassic to Lower Jurassic *Jungo terrane* (JO) in west central and north western Nevada consisting of fine-grained terrigenous clastic rocks
- the Triassic to Lower Jurassic *Walker Lake terrane* (WLB, WPL, WPN) composed of lower Mesozoic carbonate, siliclastic, volcanic and volcaniclastic rocks in Lyon, Mineral and western Nye counties which is divided into three distinct assemblages
- the *Quartz Mountain terrane* (QM), a structurally disrupted unit of unknown Mesozoic or Paleozoic age in Churchill and northern Nye counties, is distinguished lithologically by the association of orthoquartzite with feldspathic sandstone and/or volcanic rocks
- the Triassic to Lower Jurassic *Sand Springs terrane* (SAS) which extends from the northwestern corner of Nye county northwest into Washoe County, made of mostly volcanic rocks of early Mesozoic age
- and the Mississippian to Lower Jurassic *Black Rock-Jackson terrane* (BRJ) that includes carbonate, clastic and volcaniclastic rocks.

All of the rocks of these terranes have experienced varying degrees of deformation and metamorphism, and have complex tectonic histories.

Interpretation of Paleozoic rocks in Nevada has had a long and colorful history. Paleozoic rocks in Nevada are grouped into six categories that include stratigraphic sequences and lithologic assemblages; and three accreted terranes. These groupings were chosen to best represent the similarities and differences among different rock units, and are shown in the accompanying legend.

- In the eastern third of the state, the *Carbonate Shelf sequence* (Pc, Psc, PlPc, lPc, Mc, Dc, Dcd, DSc, SOc, Ocq, Oc, Cc) includes Cambrian through Permian rocks and their metamorphosed (or undivided) equivalents (DCc, DOcm, Ocqm, OCcm). While these rocks have seen significant post-Paleozoic disruption in places, the regional pattern of these rocks is one of either continuous conformable or disconformable sequences. Major unconformities are not part of this sequence.
- The *Foreland Basin assemblage* (lPMcl, MDcl) is an Upper Devonian through Lower Pennsylvanian siliciclastic sequence deposited on the western part of the Carbonate Shelf sequence. There may be unconformities within the Foreland Basin assemblage, but much of the sequence is conformable or disconformable, and lithologies above and below any breaks are similar, making them difficult to identify.
- The *Siliciclastic Overlap assemblage* (Pacl, PlPacl) is a Pennsylvanian through Lower Triassic sequence of siliciclastic and carbonate rocks sitting above a major unconformity on the Foreland Basin assemblage, Lower Paleozoic rocks of the Slope assemblage, the Basin assemblage, the Nolan Belt and the Dutch Flat terrane. Its sparse regional distribution but consistent stratigraphic (and structural) position makes it an important regional tectonic constraint. Lower Triassic rocks of the Siliciclastic Overlap assemblage are only exposed in southwestern and south-central Nevada.
- In a north-south belt in the east-central part of the state, Ordovician through Lower Mississippian rocks are grouped into the *Slope assemblage* (MDst, DSt, DOts). In places parts of this assemblage are in conformable depositional contact with Carbonate Shelf sequence rocks, and fairly coherent stratigraphic sequences can be defined. In most places, these rocks are imbricated in thrust sheets with rocks of both the Carbonate Shelf sequence and the Basin assemblage. The lithologies of the Slope assemblage reflect deeper slope and basin depositional settings.
- Rocks of the *Basin assemblage* (DOs, Ss) are exposed in a belt trending southwest and south from northeastern Nevada towards Esmeralda County. These Ordovician through Devonian rocks are characteristic of deep marine paleogeographic settings and include both sedimentary rocks and occasionally their mafic volcanic substrate. Apart from fragments of basaltic rocks, no true basement is preserved with these rocks, and they are structurally emplaced over other generally coeval rocks. They are intimately imbricated with Carbonate Shelf sequence rocks, Slope assemblage rocks, and rocks of the Nolan Belt. While biostratigraphic evidence indicates that these rocks range from Lower Ordovician through Devonian, few stratigraphic sequences can be defined within these strongly deformed rocks. The amount of displacement experienced by the rocks in this assemblage is unknown and likely highly variable.
- A belt of lower Paleozoic rocks with strong affinity to the North American continental margin but with unusual structural characteristics forms a discrete belt west and northwest of displaced rocks of the Slope and Basin assemblages, and is here named the *Nolan Belt* (OCtd, Ctd). They are different from the other Paleozoic rocks in a number of important ways that warrant distinction as a separate group. These rocks have structural characteristics of an accreted terrane, that is, they exhibit polyphase deformation, but have stratigraphic ties to North America that suggest they have not traveled great distances laterally from the continental margin. The two principal characteristics of the Nolan belt of rocks are lithologically they define a region of outer shelf and slope Cambrian and Ordovician rocks, originally deposited in a more proximal position to the

Carbonate Shelf sequence than the rocks of the Basin assemblage, some of which now lie structurally to the east of this belt, and unlike rocks of the Basin or most of the Slope assemblage, they are stratigraphically attached to their Cambrian and Precambrian Quartzite basement.

Two Paleozoic terranes are included, in addition to the Black Rock terrane described in the Mesozoic section which also contains Paleozoic rocks. These terranes represent rocks that have a range of ages and lithologies, and have structural or tectonic characteristics that make them distinct from adjacent rocks. Some of these rocks may be displaced only tens of kilometers from their places of origin, while others may be displaced by thousands of kilometers. The rocks in these terranes also have tectonic histories distinct from the rocks of the continental margin prior to the time of their accretion. The terranes were accreted by a combination of translational and compressional movement leading to large steeply dipping fault zones and many imbricate slices of deformed rocks along the boundaries between these terranes and the continental margin.

- The *Golconda terrane* (GC, GChr) is a strongly deformed group of Upper Devonian through Permian deep basinal sedimentary, distal shelf clastic, volcaniclastic and volcanic rocks. The only basement known for the Golconda terrane is Mississippian to Permian slivers of ocean floor mafic and ultramafic rocks interleaved with the deep marine sedimentary and clastic rocks. It is structurally emplaced over coeval rocks of the Pennsylvanian to Triassic Siliciclastic Overlap assemblage.
- The Upper Devonian or younger *Dutch Flat terrane* (DF) is represented by the Harmony Formation, a feldspathic sandstone long thought to be Cambrian (Roberts, 1964). It is unconformably overlain by Pennsylvanian rocks of the Siliciclastic Overlap assemblage providing an upper age limit. Its contacts with adjacent rock units are structural. It has a unique structural history, and unique lithologic characteristics. Its origin and mode of emplacement remain unknown.
- The Paleozoic rocks of the *Black Rock-Jackson terrane* (BRJ) exposed in northwestern most Nevada have stratigraphic and structural affinities with coeval rocks in the eastern Klamath Mountains. These rocks were accreted to other Mesozoic rocks in Nevada during Jurassic and/or Cretaceous time.

Finally, Precambrian to Lower Cambrian clastic rocks form the base of the Carbonate Shelf sequence in eastern and southern Nevada (CZq, CZqm, Zqs). They also form the stratigraphic base of the rocks of the Nolan Belt. They are part of a large sequence of Precambrian rocks that represent the original rifted margin of western North America. They rest unconformably over Proterozoic basement (Yfi, Xm) that is only exposed in southernmost Nevada. A breccia unit of mixed breccias (br) not classifiable elsewhere identifies locally disrupted rocks. A gneiss, schist and migmatite (MzTgn) in Elko County is the only high-grade metamorphic rock in Nevada. Ultramafic rocks including serpentine (Pzsp) are scattered in a few places around the state in adjacent to major terrane boundaries.

DETAILED EXPLANATION OF GEOLOGIC UNITS

All descriptions use information from the 1978 State Map of Stewart and Carlson, and from the accompanying text (Stewart, 1980) as well as material from each county map. Additional references are cited in the text. The numeric geologic time scale cited for each unit is taken from Harland et al. (1982).

Note: The county maps that were merged to create the statewide geology layer consist of 16 different geologic maps that do not correspond exactly with the individual counties. References are commonly made in the text to the maps, not necessarily to the counties. The complete references for each county report are listed in the bibliography. The sixteen maps and the counties (or parts of counties) they represent are as follows:

	Map Name	County	Reference
1	Churchill	Churchill	(Willden and Speed, 1974)
2	Clark	Clark	(Longwell et al., 1965)
3	Elko	Elko	(Coats, 1987)
4	Esmeralda	Esmeralda	(Albers and Stewart, 1972)
5	Eureka	Eureka	(Roberts et al., 1967)
6	Humboldt	Humboldt	(Willden, 1964)
7	Lander	Lander	(Stewart et al., 1977b)
8	Lincoln	Lincoln	(Tschanz and Pampeyan, 1970)
9	LDC	Lyon, Douglas and Carson	(Moore, 1969)
10	Mineral	Mineral	(Ross, 1961)
11	Nye North	Northern Nye	(Kleinhampl and Ziony, 1985)
12	Nye South	Southern Nye	(Cornwall, 1972)
13	Pershing	Pershing	(Johnson, 1977)
14	Washoe North	Northern Washoe	(Bonham and Papke, 1969)
15	Washoe South	Southern Washoe and Storey	(Bonham and Papke, 1969)
16	White Pine	White Pine	(Hose et al., 1976)

QUATERNARY ROCKS

Quaternary sediments and rocks reflect more inconsistency from county to county than rock units from most other age periods. Some counties differentiated older and younger alluvium and some did not, so two units were used but not always designated in each county. Sand dunes, playas and glacial moraines are also included as Quaternary units. Only one Quaternary volcanic unit, basalt flows, is designated. Older sedimentary rocks include older alluvium, older gravels, hot spring deposits, and landslide deposits. The youngest volcanic rocks in the state include Late Tertiary or Early Quaternary basalt flows, andesite, rhyolite and volcaniclastic sediments.

Quaternary Rock Units include:
Qal, *Qya*, *Qs*, *Qpl*, *Qg*, and *Qb*.

Sediments and Sedimentary Rocks

Qal - Alluvium, undifferentiated

Undivided Quaternary alluvium. This unit is present in all counties. Some counties divided the alluvium into younger and older units, and some did not. For those that did not, or used other generalized terms for Quaternary rocks, the unit Qal has been used for the general undivided alluvium. Additionally, when polygons have been edited and changed to alluvium, Qal was used as the general value; hence it now is present in all counties. Age Range: 2.5 – 0 Ma, Pleistocene to Recent.

Qya - Younger Alluvium
Younger Quaternary alluvium. It is used in Churchill, Elko, Esmeralda, Eureka, Humboldt, Lander and Lincoln Counties where geologic information suggests better defined younger versus older alluvium. It is mostly interchangeable with Qal, except that it implies some specifically younger quaternary deposits. Age Range: 2.5 – 0 Ma, Pleistocene to Recent.

Qs - Sand Dunes
Sand Dunes. This unit is present in Clark, Humboldt, Lincoln, Churchill, Washoe and Pershing Counties. There may be sand dunes in other counties that are not distinguished. Age Range: 2.5 – 0 Ma, Pleistocene to Recent.

Qpl – Playas, Lake Beds and Flood Plains
Playas, Lake Beds and Flood Plains. Used in all counties for recent lake beds, playas and flood plains. All Qp polygons from the state map were added where no playa was shown. Age Range: 2.5 – 0 Ma, Pleistocene to Recent.

Qg - Glacial Moraines
Glacial Moraines. These sediments are present in Washoe South, Nye North, Esmeralda, Elko, Humboldt, White Pine and Lander Counties in high mountain ranges. Age Range: 2.5 – 0 Ma, Pleistocene to Recent.

Volcanic Rocks
Qb – Basalt Flows
Basalt flows, plugs, cinder cones, basaltic ash, scoria, and basaltic sediments. They are present in Nye, Esmeralda and Churchill Counties. Age Range: 2.5 Ma – 0 Ma, Pleistocene to Recent.

QUATERNARY OR TERTIARY ROCKS

Quaternary or Tertiary Rock Units include:
QToa, QTg, QThs, QTls, QTs, QTb, QTa, and QTr.

Sedimentary Rocks
QToa - Older Alluvium and Alluvial Fans
This unit consists mostly of older alluvium and alluvial fans. It also includes various stream deposits, gravel, fanglomerates, and older gravels. It serves as a counterpart to Qya in some counties. It is not very consistent in description from county to county. This is used in all counties except Clark. Age Range: 6.0 - 2.5 Ma, Pliocene to Pleistocene.

QTg - Older Gravels
Older Gravels. This unit is used for pre-Lake Lahontan deposits, weakly consolidated gravel and sand, older gravels, pediment gravels and gravel deposits. It includes all units designated as QToa on the State map. This unit is used in all counties. Age Range: 6.0 - 2.5 Ma, Pliocene to Pleistocene.

QThs - Hot Spring Travertine, Sinter and Tufa
Hot Spring Travertine, Sinter and Tufa. This unit includes calcareous and siliceous sinter and tufa deposits that are present in Washoe, Nye, Elko, Eureka and Lander Counties. Age Range: 6.0 - 0 Ma, Pliocene to Recent.

QTls - Landslides, Colluvium and Talus
Landslides, colluvium and talus. This unit is mixed on the Washoe North map with basalt, tuff, diatomite and tuffaceous sediments. It includes the units mapped as Qls from the state map. It is present in Churchill, Washoe, Nye, Esmeralda, Elko, Eureka, Humboldt, Lander, Lincoln, Mineral, and Pershing Counties. Age Range: 6.0 – 0 Ma, Pliocene to Recent.

QTs - Tuffaceous Limestone, Siltstone, Sandstone and Conglomerate
Tuffaceous limestone, siltstone, sandstone and conglomerate is present in Esmeralda, Elko, Mineral, LDC and Eureka Counties and corresponds to unit QTs on the state map. Age Range: 6.0 – 0 Ma, Pliocene to Recent.

Volcanic Rocks
QTb - Basalt Flows
Olivine basalt and basaltic and andesitic rocks. This unit is present in Clark, Elko, Mineral, Esmeralda, Humboldt, Lincoln, LDC, Nye, Washoe and Lander Counties. It corresponds to the state unit QTb. Age Range: 6.0 - 2.5 Ma, Pliocene to Recent.

QTa - Andesite Flows and Breccias
Andesite and basalt flows and breccias. These rocks are present in Washoe South, Esmeralda, LDC, Mineral and Lander counties. They correspond to unit QTa on the state map. Age Range: 6.0 – 0 Ma, Pliocene to Recent.

QTr - Rhyolite Dome
Rhyolite Dome. These rocks are only present in Washoe South and Mineral counties. They correspond to unit QTr on the state map. Age Range: 6.0 – 0 Ma, Pliocene to Recent.

TERTIARY ROCKS
Most Tertiary rocks in Nevada are volcanic. There are also a few lacustrine, fluvial and tuffaceous sedimentary rocks that were deposited in Tertiary basins scattered around the state. Tertiary intrusive rocks include felsic, rhyolitic and mafic varieties.

Volcanic and Sedimentary Rocks
The naming of the Tertiary volcanic and sedimentary rocks in this map follows closely the scheme used in Stewart and Carlson (1978) with a few additions and consolidations. There are three age groupings, from youngest to oldest, T3 (17-6 Ma), T2 (34-17 Ma), and T1 (43-34). There are five primary compositional and textural groupings for the volcanic and sedimentary rocks; sedimentary (Ts3), basaltic (Tb3), andesitic (Ta3), tuffaceous (Tt3) and rhyolitic (Tr3). The distinction between the Ts units and the Tt units is that Ts represents sedimentary rocks that formed in a primary depositional environment (lake bed, fluvial, etc.) with some amount of tuff or tuffaceous sedimentary rock as part of the sequences, while the Tt units are primarily volcanic in nature (welded or non-welded tuffs) that may have interlayered tuffaceous sedimentary horizons. In addition to the scheme described above, there are a few Tertiary units (Tba, Tbg, Ths) that cross time and compositional boundaries, and they are designated separately as described below.

Tertiary Volcanic and Sedimentary Rock Units include:
Tba, Tbg, Ths, Ts3, Tb3, Ta3, Tt3, Tr3, Ts2, Tb2, Ta2, Tt2, Tr2, Ts1, Ta1, Tt1, and *Tr1*.

Tba - Andesite and Basalt Flows
Andesite and basalt flows, generally poorly age constrained. This unit includes rocks originally mapped as the Pyramid Sequence in Washoe County, the Mizpah trachyite in Nye County, the Malpai Basalt, Rabbit Spring Formation, and Mira basalt in Esmeralda County, and many other poorly dated, unnamed basaltic and andesitic rocks around the state. It corresponds to unit Tba on the state map. It is present everywhere except White Pine County. Age Range: 34 – 6 Ma, Oligocene to Miocene.

Tbg - Basalt, Gravel and Tuffaceous Sedimentary Rocks
Basalt flows, cinder and lava cones, gravel, and tuffaceous sedimentary rocks mostly in Elko and some in Humboldt counties. This unit includes most polygons of the Banbury Formation (Stewart and Carlson, 1978) and the Big Island Formation in Elko County and other unnamed units. It corresponds to the Tbg unit from the state map. Age Range: Mostly 17 - 6 Ma, Miocene.

Ths - Tuffaceous Sedimentary Rocks
Tuffaceous sedimentary rocks of the Horse Spring Formation in Clark and southern Nye Counties. This unit corresponds to unit Ths from the state map, and likely represents a composite of units Ts3 and Ts2. It is poorly known and may include rocks of other ages including Cretaceous. Age Range: 29 - 13.2 Ma, Upper Oligocene to Middle Miocene.

Ts3 - Tuffaceous Sedimentary Rocks
Tuffaceous and other young Tertiary sedimentary rocks. Most of these rocks are sedimentary with a strong volcanic component -- some are tuffaceous with a strong sedimentary component. This unit includes rocks originally mapped as the High Rock sequence in Washoe County, the Horse Camp Formation in northern Nye County, the Esmeralda Formation in Mineral and Esmeralda Counties, Older Lake beds in Lincoln County, the Belted Range Tuff, Indian Trail, Timber Mountain, Paintbrush, Crater Flat Tuff, Wahmonie, and Salyer Formations in southern Nye County, the Siebert Tuff in Esmeralda County, the Muddy Creek Formation in Clark County, and the Thousand Creek and Virgin Valley beds in Humboldt County and other unnamed units. It corresponds to units Ts3 and Tts from the state map. It is present in all counties. Age Range: 17-6 Ma, Miocene.

Tb3 – Basalt
Basalt flows, plugs and dikes, some olivine basalt and andesite and latitic rocks. This unit corresponds with unit Tb on the state map. It is present on the Washoe North, Washoe South, Lincoln, Clark, Elko, Eureka, Humboldt, Nye South and Lander County maps. Age Range: 17-6 Ma, Miocene.

Ta3 - Andesite/Intermediate Flows and Breccias
Andesite to intermediate flows and breccias. This unit includes some rocks mapped as the Kate Peak and Alta Formations on the Washoe South map, Wahmonie and Salyer Formations on the Nye South map, Gilbert Andesite on the Esmeralda map, and pyroxene and hornblende phenoandesite and phenodacite on the Elko map and other unnamed units. It corresponds to the

unit Ta3 on the state map. It is present everywhere except Eureka and White Pine Counties. Age Range: 17 – 6 Ma, Miocene.

Tt3 - Silicic Ash Flow Tuffs
Silicic ash flow tuffs. This rock unit includes some polygons mapped as the High Rock Sequence on the Washoe North map; the Timber Mountain, Paintbrush, Crater Flat, and Belted Range Tuffs and Indian Trail Formation on the Nye South map and the Thirsty Canyon Tuff on the Nye South and Esmeralda maps and other unnamed units. Locally it includes tuffaceous sedimentary rocks interstratified with tuffs. It is present in the northernmost part and southernmost parts of the state, and is not exposed in the central region. It corresponds to unit Tt3 on the state map, although a few rocks also mapped as Trt also are included. It is present in Clark, Churchill, Washoe, Nye, Lincoln, LDC, Esmeralda, Elko, Humboldt, Pershing and Mineral Counties. Age Range: 17 – 6 Ma, Miocene.

Tr3 - Rhyolitic Flows and Shallow Intrusive Rocks
Rhyolitic flows, domes, plugs, breccias, quartz latite, rhyodacite, quartz porphyry dikes and other shallow intrusive rocks. This unit includes rocks mapped as the Canon Rhyolite on the Washoe North map, the Jarbidge Rhyolite and phenorhyolitic and phenodacitic flows and domes on the Elko County map and other unnamed units. It has a distribution similar to Tt3, with exposures in the northern and southern parts of the state, but only a few in the central region. It corresponds to unit Tr3 on the state map, and also includes a few rocks mapped as Trt on the state map. This unit is exposed in every county except White Pine. Age Range: 17 – 6 Ma, Miocene.

Ts2 - Tuffaceous Sedimentary Rocks
Tuffaceous sedimentary rocks, locally includes minor amounts of tuff. It includes rocks mapped as the Titus Canyon Formation on the Nye South map, the Gilmore Gulch Formation on the Nye North map, lacustrine limestone in Lincoln County and other unnamed units. This unit corresponds to unit Ts2 on the state map. It is present in Nye South, Nye North, Lincoln, Elko and Lander Counties. Age Range: 34 – 17 Ma, Oligocene to Lower Miocene.

Tb2 - Basalt, Tuff and Breccia
Basalt flows, basaltic tuff, tuff breccia and andesitic rocks in Elko and Humboldt Counties. These rocks correspond to unit Tob on the state map. Age Range: 34 – 17 Ma, Oligocene to Lower Miocene.

Ta2 - Andesite/Intermediate Flows and Breccias
Andesite flows and breccias and other related rocks of intermediate composition such as dacite, rhyodacite, quartz latite and biotite-hornblende porphyries. This unit includes polygons mapped as the South Willow Formation on the Washoe North map, the Milltown Andesite on the Nye South and Esmeralda County maps and the Mizpah trachyte on the Nye North map and other unnamed units. It corresponds to unit Ta2 on the state map. It crops out in all counties except Clark, Eureka and LDC. Age: 34 – 17 Ma, Oligocene to Lower Miocene.

Tt2 - Silicic Ash Flow Tuff
Welded and non-welded silicic ash flow tuffs. Aside from alluvium, this unit covers more of Nevada than any other rock, with over 4,000 polygons representing it on this map, principally

exposed in central regions of the state. It locally includes thin units of airfall tuff and sedimentary rocks. It includes rocks mapped on the Washoe South and LDC maps as the Hartford Hill rhyolite, on the Nye South map as the Tuff of White Blotch Spring, the Tuffs of Antelope Springs, and the Tuff of Monotony Valley; in Lander County it is mapped as the Bates Mountain Tuff, Caetano Tuff, Edwards Creek tuff, New Pass Tuff, Tuff of Hall Creek, and the Tuff of McCoy Mine; in Lander and Pershing Counties, it is the Fish Creek Mountain Tuff, on the Nye South and Nye North maps the Fraction tuff; also includes on the Nye North map the Pancake Summit tuff, Northumberland tuff, Shingle Pass tuff, some outcrops of Darrough felsite, tuffs of Moores station, Tuffs of Peavine Canyon, tuffs of the Pancake Caldera complex, the Stone Cabin Formation, tuff of Saulsbury Wash, tuff of Kiln Canyon, the Tonopah formation, Tuffs of Hannapah, Tuff of Bald Mountain, the Needles Range Formation, and the Calloway Well Formation; in Esmeralda County it is the Kendall Tuff and latite; and in Nye North and Lander it is the Toiyabe quartz latite and other unnamed units. It corresponds to unit Tt2 on the state map. It crops out in every county except Clark. Age Range: 34 – 17 Ma, Oligocene to Lower Miocene.

Tr2 - Rhyolitic Flows and Shallow Intrusive Rocks
Rhyolitic flows and shallow intrusive rocks. This unit includes rocks mapped as the rhyolite of Big Sand Springs Valley on the Nye North map, the Sandstorm Formation in Esmeralda County, rhyolite flow domes in the Sheep Creek Range in Lander County, and other unnamed units. It corresponds to unit Tr2 on the state map. It is present in Nye, Lincoln, Churchill, Esmeralda, Eureka, Mineral, Elko, Humboldt and Lander Counties. Age Range: 34 – 17 Ma, Oligocene to Lower Miocene.

Ts1 – Lacustrine and Tuffaceous Sedimentary Rocks
Conglomerates, lacustrine and tuffaceous sedimentary rocks. This unit includes the Sheep Pass Formation and equivalents in northern Nye, Lincoln, Elko, Eureka, Lander and White Pine Counties. It corresponds to unit Ts1 on the state map. Age Range: 43 – 34 Ma, Middle Eocene to Lower Oligocene.

Ta1 - Andesite/Intermediate Flows and Breccias
Andesite and latitic rocks, flows and breccias. This unit is present in Humboldt, northern Nye, Churchill, Elko, Eureka, Lander and White Pine Counties. It corresponds to state map unit Ta1. Age Range: 43 – 34 Ma, Middle Eocene to Lower Oligocene.

Tt1 - Silicic Ash Flow Tuffs
Welded and non-welded silicic ash flow tuffs, locally includes thin units of air-fall tuff and sedimentary rock. This unit corresponds with state unit Tt1. These rocks are present in northern Nye, Elko, Eureka and White Pine Counties. Age Range: 43 – 34 Ma, Middle Eocene to Lower Oligocene.

Tr1 - Rhyolitic Flows and Shallow Intrusive Rocks
Rhyolitic flows and shallow intrusive rocks. This unit includes rhyolitic lava of Portugese Mountain in northern Nye County, the Frenchie Creek rhyolite in Elko County and other unnamed units. It corresponds to unit Tr1 on the state map. It is present in northern Nye, Elko, Eureka and White Pine Counties. Age Range: 43 – 34 Ma, Middle Eocene to Lower Oligocene.

Intrusive Rocks

The groupings for Tertiary intrusive rocks are compositional and three compositions, felsic intrusive (Tfi), rhyolite intrusive (Tri) and mafic intrusive (Tmi) are shown. More detail on definitions of intrusive rocks is provided under Mesozoic Intrusive Rocks.

Tertiary Intrusive Rock Units include:
Tfi, Tri, and Tmi

Tfi – Felsic Intrusion

Tertiary felsic intrusive rocks are widely scattered in every county across the state. They are generally described as granitic rocks, granodiorite, monzonite, quartz monzonite, alaskitic granite, quartz diorite, dacite and rhyodacite in the places where they are shown separately on county maps. Age Range: 43-6 Ma, Eocene to Miocene.

Tri - Rhyolite Intrusion

Tertiary rhyolite intrusive rocks also are present in nearly every County of Nevada. They include many rocks mapped as rhyolite or rhyolite porphyry, rhyolite intrusive rocks, rhyolite plug or flow, and microgranite dikes, and many other undifferentiated intrusive rocks. Age Range: 43-6 Ma. Middle Eocene to Miocene.

Tmi – Mafic Intrusion

Tertiary mafic intrusive rocks are widely scattered across Nevada north of Clark County. They include rocks mapped as dacite and rhyodacite, diorite, quartz latite, and numerous undivided intrusive rocks on the county maps. Age Range: 43-6 Ma, Middle Eocene to Miocene.

MESOZOIC OR TERTIARY INTRUSIVE ROCKS

These rocks are poorly constrained in age, and are shown only as mafic or felsic intrusions. They could range in age from Tertiary to Jurassic. See the description below under Mesozoic intrusions for more details about the unit definitions.

Unknown age Intrusive Rock Units include:
TJfi and TJmi

TJfi – Felsic Intrusion

Poorly dated felsic intrusions described as granitic rocks, granite porphyry, granodiorite, quartz monzonite, and many undivided plutonic rocks are included here. They crop out in every county except Elko and northern Washoe. Age Range: 213 – 6 Ma, Jurassic to Miocene.

TJmi – Mafic Intrusion

Poorly dated mafic intrusions are concentrated in two regions of Nevada, northwestern, and west-central to southwest parts of the state. They crop out in northern Nye, Mineral, Esmeralda, Eureka, Humboldt and Lander counties, and include rocks described on the county maps as dioritic to andesitic rocks, diorite and related rocks and granodiorite. Age Range: 213 – 6 Ma, Jurassic to Miocene.

MESOZOIC ROCKS

Mesozoic intrusive, volcanic, sedimentary, and metamorphic rocks, many associated with accreted terranes, are all present in Nevada. These rocks formed in a variety of tectonic environments and depositional settings and they reflect many diverse structural and tectonic histories. A few Triassic, and numerous Jurassic and Cretaceous plutons of various compositions are scattered across the state, with a concentration along the Sierra Nevada associated with Mesozoic arcs. Mesozoic volcanic rocks ranging in composition from felsic to mafic are spread across the central part of the state. Their tectonic settings and origins are not well understood, but they are likely related to Triassic and Jurassic arc complexes, and possibly also to accreted terranes. Twelve different groupings of Mesozoic sedimentary and volcaniclastic rocks are recognized in the state. They include clastic rocks and conglomerates that lie unconformably over older, folded and faulted rocks, distinct stratigraphic sequences in the southern, eastern and central parts of the state, and numerous different assemblages with distinct stratigraphic and structural histories that are juxtaposed in several different terranes along tectonic boundaries in the western half of the state.

Intrusive Rocks

Intrusive rocks include many Jurassic and Cretaceous plutons ranging in composition from diorite to granite – predominantly granodiorite and quartz monzonite. The classification scheme for the intrusive rocks is a designation by age (Triassic, Jurassic, Cretaceous, Tertiary, or Tertiary-Jurassic, indicating no age control) and composition, and is very generalized, taken primarily from designations given in Stewart and Carlson (1978). Rocks are designated as either *felsic intrusive* (*fi)* or *mafic intrusive (mi)*. Where composition is poorly known, rocks are designated *intrusive rock (ir)*, or *granitic rock (gr)*. A more comprehensive analysis of intrusive rock compositions using actual modal data will be presented in a separate publication.

Mesozoic Intrusive Rock Units include:
Kir, Kfi, Kmi, Jfi, Jgr, Jmi, Jgb, and TRfi.

Kir – Intrusive Rocks

These dike rocks of unknown composition are mapped in the Sahwave Mountians in Pershing County, the Osgood Mountains and Edna Mountain in Humboldt County, and just outside Eureka. Age Range: 144 – 65 Ma, Cretaceous.

Kfi – Felsic Intrusion

Granodiorite, granite and related rocks make up the largest group of granitic intrusive rocks exposed in Nevada. They are present in every county, and are especially abundant in west central Nevada in an arcuate belt along the border with California extending north and eastward towards Idaho. Age Range: 144 – 65 Ma, Cretaceous.

Kmi – Mafic Intrusion

Rocks mapped as Cretaceous dioritic rocks only crop out in northern Nye County in the San Antonio Mountains, and in a belt in far northwestern Nye County from the Monte Cristo Mountains east to the Shoshone Mountains. Age Range: 144 – 65 Ma, Cretaceous.

Jfi – Felsic Intrusion

Jurassic felsic intrusive rocks are concentrated in two areas of the state. They are common in the west-central part of the state along the California border in Mineral, Esmeralda, and LDC counties. There is another more widely scattered group in eastern and central Nevada in Elko, Eureka and White Pine counties. Scattered occurrences also are present in Humboldt, Churchill, Lander and Pershing counties. Compositions are mainly granitic, granodiorite and quartz monzonite. Age Range: 213 – 144 Ma, Jurassic.

Jgr – Granitic Rock

Quartz Monzonite to Quartz Diorite crops out in west-central Nevada in the Singatse Range in Lyon County, the Gillis Range in Mineral County, the Toquima Range on the Nye/Lander boundary, and in northern Nevada at Buffalo Mountain in Humboldt County and in the East Range in Pershing County. Age Range: 213 – 144 Ma, Jurassic.

Jmi – Mafic Intrusion

Jurassic mafic intrusive rocks include diorite in northern Elko County, diorite to granodiorite in the Toquima Range of northern Nye county, and dioritic and gabbroic rocks in western Churchill County. Age Range: 213 – 144 Ma, Jurassic.

Jgb - Gabbro complex, Anorthosite and Albitite

Gabbroic rocks. A large complex of gabbroic rocks forms a series of related intrusions in the northern parts of the Stillwater Range and Clan Alpine Mountains of Churchill County and in the West Humboldt Range of Pershing County (Willden and Speed, 1974). It also may extend into the Trinity Range and Shawave Mountains in western Churchill County (Greene et al., 1991). The complex contains highly differentiated facies near the periphery of the body and more homogeneous gabbro in the interior. Layered rocks near the margins include picrite, olivine gabbro, hornblende gabbro, and anorthosite. The homogeneous rocks consist largely of feldspathic hornblende gabbro and analcite gabbro. The complex is interpreted to be part of a continental Jurassic volcanic arc that is the northern continuation of a Jurassic continental margin arc that extended from the Sonora Desert region in the south to northern California in the north (Dilek and Moores, 1995; Zientek et al., 2004). Biotites from several places in the gabbro have been dated by K/Ar and range from 170 to 140 Ma, suggesting a Middle to Late Jurassic age. Age Range: 170 - 140 Ma, Jurassic to Earliest Cretaceous.

TRfi – Felsic Intrusion

Triassic felsic intrusive and volcanic rocks crop out in the East Range and Humboldt Range in Pershing County associated with the Koipato Group volcanic rocks (TRkv). They intrude upper Paleozoic rocks of the Golconda terrane (GC). Another small group of rocks between the Royston Hills and the Monte Cristo Range in Esmeralda County may be of similar composition, and has yielded Triassic radiometric ages. These rocks also intrude into the Golconda terrane (GC). Age Range: 248 – 213 Ma, Triassic.

Volcanic Rocks

Triassic volcanic rocks are only present in west-central Nevada. They include the Koipato Group (TRkv) volcanic and sedimentary rocks which unconformably overlie the Golconda terrane in a large area of eastern Pershing County and mafic volcanic rocks (TRvm) in the Humboldt and East Ranges in Pershing County that are present as flows interbedded with Triassic carbonate rocks. Jurassic felsic volcanic rocks (Jvr) are isolated in the Cortez Mountains and Dry Hills around Crescent Valley in northern Eureka County near Carlin. Jurassic basaltic rocks (Jvb) are present in Churchill County in the Stillwater Range associated with Jurassic gabbro (Jgb) and quartzose sandstone (Jcg). In far western Nevada around Reno, a sequence of Triassic-Jurassic metamorphosed volcanic rocks (JTRv) is dissimilar to other Mesozoic rocks in the area, and may represent a distinct terrane.

Mesozoic Volcanic Rock Units include:
Jvr, Jvb, JTRv, TRvm, TRkv

Jvr - Rhyolite Flows, Tuffs and Volcaniclastic Rocks
Rhyolite flows, felsic ash-flow tuffs and volcaniclastic rocks of the Pony Trail Group (Muffler, 1964) are the only recognized Jurassic felsic volcanic rocks in Nevada, cropping out in northern Eureka County in the Cortez Mountains area. They are dated as Jurassic by a radiometric date from 1972 (Smith and Ketner, 1976). The Pony Trail Group is made up of the volcaniclastic Big Pole Formation; a silicic ash-flow tuff unit, the Sod House Tuff; and the boldly outcropping Frenchie Creek Rhyolite made of tuffs, volcaniclastic horizons and flows (Smith and Ketner, 1976). While some of these rocks likely are Jurassic, rocks mapped on the Elko County map as the Frenchie Creek Rhyolite exposed in the Elko Hills northeast of Elko have been shown to be Tertiary and renamed (Ketner, 1990) so it is possible that parts of the section are not Jurassic. This unit corresponds to unit Jv on the state map. Age Range: 154 – 148 Ma, Late Jurassic.

Jvb - Flows, Basaltic Tuffs and Lapilli Tuffs
Layered tuff, lapilli tuff, bedded agglomerate, tuff breccia, autobreccia, and lava, chiefly basaltic. Jurassic mafic volcanic rocks are present in the Stillwater Range in Churchill County, with smaller exposures in the West Humboldt Range. In the Stillwater Range they are intimately associated with gabbroic intrusive rocks (Jgb). They conformably overlie and locally are interbedded with quartz arenite (Jcg). The lavas are homogeneous basalts that contain microphenocrysts of labradorite, diopsidic augite, and talc-hematite after olivine. The groundmass is plagioclase-clinopyroxene-iron oxide (Willden and Speed, 1974). They are believed to be Middle Jurassic because they are thought to be comagmatic with the gabbro (Jgb). This unit is included within the state unit Jgb. Age Range: 213 – 144 Ma, Jurassic, possibly Middle Jurassic (188-163 Ma).

JTRv - Metavolcanic Rocks
Metamorphosed (generally greenschist-facies) andesite and dacite flows and breccias, flow-banded rhyolite and rhyodacite, welded tuff, local hypabyssal intrusive rocks, and minor amounts of volcaniclastic sandstone and conglomerate (Greene et al., 1991). This unit includes the Peavine Sequence in Washoe County, and other unnamed metasedimentary and metavolcanic rocks in LDC and Churchill Counties. These rocks are considered distinct from the other metavolcanic and metasedimentary rocks in adjacent Mesozoic terranes. They are included in unit JTRsv on the state map. Age Range, 248 – 144 Ma, Triassic – Jurassic.

TRvm – Mafic flows and volcanic breccias
Amygdaloidal, nonporphyritic, massive flows and breccia, tuff and tuffaceous argillite are interbedded with limestones in the Smelser Pass member of the Augusta Formation in the Star Peak Group Triassic sedimentary rocks (TRc) in Pershing County (Nichols and Silberling, 1977b). They are well dated by abundant fossils from the surrounding rocks and range from lower Middle Triassic (Anisian) to lower Upper Triassic (Carnian) (Silberling and Wallace, 1969). They are not divided out on the state map from surrounding Triassic Carbonate TRc. Age Range: 243 – 225 Ma, lower Middle Triassic to lower Upper Triassic.

TRkv - Andesite, Rhyolite, Tuff and Volcaniclastic Rocks
Andesite, rhyolite, tuff and generally siliceous volcaniclastic rocks make up the Koipato Group, the basal member of the Humboldt assemblage (Oldow, 1984a). The Koipato Group consists of altered porphyritic andesite flows and flow breccia of the Limerick Greenstone; altered felsite and coarse-grained tuffaceous sedimentary rocks of the Rochester Rhyolite; and quartz rich ash-flow tuff and tuffaceous sedimentary rocks of the Weaver Rhyolite. It is present in Churchill, Humboldt, Lander and mostly Pershing Counties where it unconformably overlies deformed rocks of the Golconda terrane (GC). The upper part of the Koipato contains late Early Triassic (Spathian) fossils (Wallace et al., 1969; Silberling, 1973). It is depositionally overlain by the Star Peak Group (TRc), a sequence of carbonate platform deposits. Radiometric dates from the 1970's suggest an Early to Middle Triassic age. Age Range: 248 – 231 Ma, Lower to Middle Triassic.

Sedimentary Rocks and terranes
Mesozoic sedimentary rocks are difficult to classify because of the diversity of their structural histories, depositional settings, and basements coupled with our incomplete knowledge of their relations to one another. Generally, they can be grouped into two categories – those sequences that are deposited on a known basement, and those sequences that are strongly disrupted and their basement is either unknown or intimately deformed along with them as part of a larger terrane. In places where the Mesozoic rocks have a complex deformation history, they are not grouped by formation, but rather they are grouped as either terranes or assemblages. Terranes are used in the classic sense for fault-bounded geologic entities of regional extent, each characterized by a geologic history that is different from the histories of contiguous terranes (Jones et al., 1983). Assemblage, an informal term, is used for a group of related rock units within a terrane, or for a unit (or units) that has a known basement, but is geographically isolated and lithologically and(or) structurally distinct from other coeval rocks. This can result in formation names being used across assemblages, but it provides a clearer picture of the tectonic groupings of the rocks. This, in turn, provides the framework for understanding the overall tectonic evolution of these rocks and how their complex relations to one another have evolved over time. The groupings used here generally follow earlier terrane maps and discussions (Silberling et al., 1987; Silberling, 1991; Silberling et al., 1992) with a few modifications.

The rocks that are deposited on a known basement include:

- the *Cratonal sequence* (TRmt, JTRch, Jas) in the eastern and southern parts of the state
- the Candelaria Formation (TRcl) of the *Siliciclastic Overlap assemblage* best exposed south of Mina
- the *Humboldt assemblage* (TRc, JTRs) in a large area of Pershing, Churchill and Lander Counties
- the *Gold Range assemblage* (JTRgor) in Mineral and western Nye counties
- and *Localized Clastic rocks* (TKcg, Kcg, Jcg) scattered in several places across the state.

The disrupted rocks with unknown basement include those in:

- the *Jungo terrane* (JO) in west central and north western Nevada consisting of Triassic to Lower Jurassic fine-grained terrigenous clastic rocks

- the *Walker Lake terrane* composed of lower Mesozoic carbonate, siliclastic, volcanic and volcaniclastic rocks in Lyon, Mineral and western Nye counties which is broken into three distinct assemblages (WLB, WPL, WPN)
- the *Quartz Mountain terrane* (QM) a structurally disrupted unit of unknown Mesozoic or Paleozoic age in Churchill and northern Nye counties, is distinguished lithologically by the association of orthoquartzite with feldspathic sandstone and/or volcanic rocks
- the *Sand Springs terrane* (SAS) which extends from the northwestern corner of Nye county northwest into Washoe County, made of mostly volcanic rocks of early Mesozoic age
- and the *Black Rock-Jackson terrane* (BRJ) that includes Mississippian to Lower Jurassic carbonate, clastic and volcaniclastic rocks.

All of the rocks of these terranes have experienced varying degrees of deformation and metamorphism, and have complex tectonic histories.

Cratonal Sequence
Marine and continental deposits of Triassic and Jurassic rocks crop out east of 116° Longitude. They can be correlated with similar deposits present to the east on the Colorado Plateau and eastward across the western United States. The older Triassic rocks are marine (TRmt) and they grade upward in a depositional sequence into continentally derived rocks (JTRch) and crossbedded sandstone (Jas).

Cratonal Sequence Rock Units include:
Jas, JTRch, TRmt, and TRcl

Jas - Eolian Crossbedded Sandstone
Aztec Sandstone. This unit is a friable fine- to medium-grained sandstone with conspicuous large scale cross strata (Stewart and Carlson, 1978). It is considered eolian. Its age is wholly Jurassic and does not include Triassic rocks as indicated on the 1978 State Map (Stewart, 1980). The Aztec is the westward continuation of the Navajo Sandstone of the Colorado Plateau. It crops out only in southern Nevada in Clark and Lincoln Counties. Age Range: 213 – 144 Ma, Jurassic.

JTRch - Continentally Derived Siltstone and Clay
These continental deposits include variegated bentonitic clay-stone, siltstone and clayey sandstone; ledge forming sandstone and red siltstone (Stewart and Carlson, 1978). The lower part of this unit is equivalent to the Upper Triassic Chinle Formation and the upper part corresponds to the Moenave and Kayenta Formations which are now considered Lower Jurassic (Stewart, 1980). It crops out in Elko, Lincoln and Clark Counties. Age Range: 231 – 188 Ma, Upper Triassic to Lower Jurassic.

TRmt - Marine Siltstone, Limestone and Conglomerate
This unit consists of marine deposits of siltstone, sandstone, claystone, mudstone, limestone and conglomerate (Stewart and Carlson, 1978). It includes rocks assigned to the Moenkopi and Thaynes Formations and related unnamed rocks in northern Nevada (Stewart, 1980). It crops out in the eastern part of the state in Elko, White Pine, Lincoln and Clark Counties. Age Range: 248-243 Ma, Lower Triassic.

Siliciclastic Overlap assemblage
The Candelaria Formation (TRcl) is the only Mesozoic unit grouped with the Upper Paleozoic Siliciclastic Overlap assemblage which is discussed in more detail under Paleozoic rocks.

Mesozoic Silicilastic Overlap assemblage Rock Units include:
TRcl. See other siliciclastic overlap assemblage rocks under Paleozoic rocks.

TRcl – Shale, Sandstone and Limestone
Shale with interbedded sandstone and minor limestone characterize the Lower Triassic Candelaria Formation (Ferguson et al., 1954). This vertically coarsening sequence grades up into a distal volcanogenic turbidite in the middle and a proximal turbidite and breccia near the top (Stewart, 1980). The basal strata of the Candelaria are earliest Triassic (Griesbachian) and the highest are late Early Triassic (early Spathian) (Speed et al., 1989). It is equivalent in age to the marine Dinwoody Formation of northwestern Utah and southeastern Idaho, and possibly, to the lower part of the predominantly volcanic Koipato Group in northwestern Nevada (Poole and Wardlaw, 1978). The Candelaria Formation is mainly exposed near the old mining camp of Candelaria, located a little more than 20 miles south of Mina, in Mineral County. Another exposure also has been described from the southern Toquima Range in Nye County, and a collection of Early Triassic fauna was recovered from flaggy brown siltstone from the west side of the Toiyabe Range east of Ione (Poole and Wardlaw, 1978). Early Triassic conodonts in clastic rocks in the northern Hot Creek Range near Morey Peak suggest that some of these rocks must be correlative with the Candelaria. These additional early Triassic locals suggest that the Candelaria may have been more extensive, or is still unrecognized elsewhere in the central part of the state. The nature of the basal contact is critical to determining the appropriate paleogeographic setting, and regional grouping for this unit. If the basal contact is a major structure, then the Candelaria likely represents a section of one of the many Mesozoic terranes that have been emplaced from the west. If the contact is fundamentally sedimentary, albeit slightly unconformable, then it constrains an important piece of the paleogeographic tectonic puzzle of Nevada geology. The Candelaria Formation sits on the subjacent Permian Diablo Formation where it is described as unconformable by Ferguson et al. (1954), conformable by Speed (1977), and nearly conformable by Page (1959). The Candelaria near Willow Spring in the Toquima Range is described as a “probable unconformity” by Poole and Wardlaw (1978). The map relations for this unit suggest that the base is a disconformity or slight unconformity with the underlying Diablo Formation (Ferguson et al., 1954; Page, 1959), but not a major structure. The Diablo formation, included here with the Permian siliciclastic overlap assemblage, lies with marked unconformity on Lower Paleozoic basinal rocks of chert, argillite and shale, as discussed below. The Candelaria Formation is unusual in that it is the oldest Mesozoic sedimentary sequence known in Nevada, and is present in a restricted area only over the Permian rocks of the siliclastic overlap assemblage, suggesting it was originally deposited directly on those rocks. The presence of volcaniclastic rocks in the upper part of the section is an important tectonostratigraphic link to the rocks of adjacent terranes. Rocks near Quinn River, Nevada that are almost as old and contain volcaniclastic rocks in the upper part of the section, belong to the Black Rock terrane (Jones, 1990; Blome and Reed, 1995). Triassic rocks of similar age exposed south of Jarbidge in northeastern Elko County are juxtaposed with Permian rocks of the siliciclastic overlap assemblage, and may correlate with the Candelaria, but the base of the section is unknown, and no volcanic facies are reported from those rocks, so they are currently included with the Cratonal sequence, TRmt. Age Range: 248-243 Ma, Lower Triassic.

Humboldt assemblage
A thick carbonate and clastic sequence of Triassic and Early Jurassic age (TRc, JTRs) was deposited on top of the Lower Triassic volcanic Koipato Group (TRkv) throughout a large area of Pershing, Churchill and Lander Counties (Oldow, 1984a). These sedimentary rocks crop out in central Nevada and are geographically isolated and stratigraphically distinct from stratigraphic sequences to the east. They exhibit varying degrees of deformation, but can still be defined as coherent sequences of strata. They may be paleogeographically related to rocks of similar ages and facies that are part of accreted terranes now located to the west, but each terrane and assemblage has somewhat different structural and stratigraphic characteristics.

Humboldt assemblage Rock Units include:
JTRs, *TRc*

JTRs – Shale, Siltstone, Sandstone and Minor Carbonate
Shale, mudstone, siltstone, sandstone and minor carbonate rocks of the Grass Valley, Osobb, Dunn Glen and Winnemucca Formations, exposed in Pershing, Churchill, Lander and Humboldt Counties characterize this unit. These rocks are depositional on top of the Star Peak Group carbonate and detrital rocks (TRc). Crossbedding, lode casts and other depositional features indicate uniform northwest-trending current directions. The lithology and depositional characteristics of these rocks suggest shallow marine conditions on and around a westerly prograding delta (Silberling and Wallace, 1969). Fossils from these rocks range in age from Late Triassic (Norian) to Early Jurassic (Toarcian) (Silberling and Wallace, 1969). Age Range: 225 – 188 Ma, Upper Triassic to Lower Jurassic.

TRc - Limestone, Dolomite, Shale, Sandstone and Conglomerate
This unit consists of limestone, dolomite, shale, sandstone and conglomerate of the Star Peak Group which sits depositionally on the volcanic and volcaniclastic rocks of the Koipato Group (TRkv). It includes rocks mapped as Natchez Pass, Prida, Cane Spring, China Mountain, Augusta Mountain, Tobin, Dixie Valley, Fossil Hill, Congress Canyon and Favret Formations and their associated members including Smelser Pass, Panther Canyon, and Home Station members of the Augusta Mountain Formation. Basaltic flows and volcanic breccias (TRvm) are present in the Humboldt and northern Stillwater Ranges within the Smelser Pass Member of the Augusta Formation. The Star Peak Group includes carbonate platform deposits and grades westward into slope and basin environments. Complex stratigraphic patterns of carbonate and terrigenous rocks in the lower part of the Group result from localized relative uplift. Widespread diagenetic secondary dolomitization of calcareous rocks complicates the stratigraphic patterns (Nichols and Silberling, 1977b). There is a major unconformity within the Star Peak Group underneath the Panther Canyon Member, which is late Ladinian (upper Middle Triassic) in age. The Panther Canyon Member rests in places directly on the noncarbonate rocks of either the Koipato Group (TRkv) or the Golconda terrane (GC), and elsewhere on varying thicknesses of secondary dolomite that replaces Star Peak Group carbonate rocks. The Star Peak Group crops out in Churchill, Humboldt, Lander and mostly Pershing Counties. Abundant fossil data from the Star Peak Group indicates this unit is latest Early (Spathian) to middle Late (Carnian) Triassic in age (Nichols and Silberling, 1977b). Age Range: 243(+) – 225 Ma, latest Early (Spathian) to middle Late (Carnian) Triassic.

Gold Range assemblage

JTRgor – Terrigenous Clastic and Volcanogenic Rocks

The Gold Range assemblage consists of mainly nonmarine, terrigenous clastic and volcanogenic rocks of probable Late Triassic to Middle Jurassic ages and local volcanic rocks having younger Mesozoic radiometric ages (Silberling, 1991). It is sitting with angular unconformity over Permian rocks included in the Golconda terrane (GC). The oldest rocks are interbedded, subaerial and shallow-marine terrigenous clastic, volcaniclastic and minor carbonate rocks overlain by shelf carbonates containing Lower Jurassic pelecypods. Unfossiliferous quartz arenite and coarse-clastic rocks disconformably overlie the shelf carbonate and grade upward into poorly-sorted volcanogenic sandstone and coarse-clastic rocks (Oldow, 1984a). The assemblage is deformed by NE trending folds associated with the overlying Luning thrust as well as younger NW trending folds (Oldow, 1984a). Speed (1977a) originally named these rocks the Gold Range Formation, derived from rocks first mapped as the Excelsior Formation. Oldow (1981) renamed some of these rocks the Water Canyon assemblage. These rocks were included with the Paradise terrane (Silberling et al., 1987; Silberling et al., 1992), but have been separated here in agreement with Silberling (1991). Silberling (1991) used “Gold Range terrane” to include the unconformably underlying Permian rocks of the Mina Formation. Since the basement rocks are here included with the Golconda terrane, the term “Gold Range assemblage” is used only for the Mesozoic rocks unconformably overlying the Permian basement. The Gold Range assemblage is in the same tectonostratigraphic position as the Humboldt assemblage--both packages are overlying rocks included in the Golconda terrane with a strong angular unconformity. While these assemblages are similar in overall age, they have different stratigraphic sequences and thus paleogeographic settings. The exact stratigraphy of the Gold Range assemblage and whether or not it includes younger Cretaceous volcanic rocks (Stewart, 1980; Silberling et al., 1987) is not clear. This assemblage crops out in Esmeralda, Mineral and northern Nye counties. Age Range: 231-188 Ma, Upper Triassic to Lower Jurassic, possibly younger.

Localized Clastic Rocks

Scattered occurrences of Mesozoic conglomeratic rocks and sandstone (TKcg, Kcg, Jcg) are present in several places in Nevada. They lie unconformably over older, deformed rocks thus serving as important age constraints on underlying rocks and deformation. Their isolated occurrences are significant indicators of local and regional tectonic events, but their ages are generally poorly constrained.

Localized Clastic Rock Units include:
TKcg, Kcg, Jcg

TKcg - Conglomerate and Clastic Rocks

These conglomeratic, tuffaceous and other clastic rocks are not well enough constrained to be assigned either a Tertiary (Ts1) or Cretaceous (Kcg) age, so they are grouped as TKcg. Like the Cretaceous clastic unit Kcg, these rocks sit unconformably on many different age rocks. Included in this unit are “Older clastic rocks” in Lincoln County; conglomerate, clastic rocks and tuff in northern Nye County; the Gale Hills Formation in Clark County and the Pansy Lee Conglomerate in the Krum Hills and Jackson Mountains in Humboldt County. Age Range: 144 - 24.6 Ma, Cretaceous to Paleogene.

Kcg - Siltstone, Shale, Conglomerate and Limestone
This unit includes detrital deposits of continental origin, and locally derived fluvial and lacustrine clastic rocks, some interbedded with siltstone and fresh water limestone. Outcrops are concentrated in three separate areas of the state. In each place, limited biostratigraphic data indicate these rocks are Cretaceous. The King Lear Formation in the Jackson Mountains in Humboldt County lies unconformably on Triassic and older rocks of the Black Rock-Jackson terrane. The Newark Canyon Formation crops out mostly in Eureka and White Pine Counties but extends into Elko and Nye as well, and rests unconformably on Ordovician to Permian rocks. In places it is difficult to distinguish Upper Devonian and Pennsylvanian-Permian clastic rocks also derived from the nearby underlying bedrock from the Newark Canyon Formation and some confusion still exists. The Willow Tank Formation in Clark County lies unconformably on Jurassic rocks and is overlain by the Baseline Sandstone and Overton Fanglomerate, all of Cretaceous age. Age Range: 144 – 65 Ma, Cretaceous.

Jcg – Conglomerate, Limestone and Quartz Sandstone
The Boyer Ranch Formation in the Clan Alpine and Stillwater Ranges in Pershing and Churchill Counties consists of a basal conglomerate overlain by partly silicified limestone which is overlain by quartz sandstone. In places it rests unconformably over Upper Triassic or younger rocks (Speed and Jones, 1969) of the Jungo (JO) terrane, constraining its maximum age, and elsewhere it is faulted over late Triassic and Early Jurassic rocks (Speed and Jones, 1969). The occurrence of conglomerate-bearing clasts of underlying units at the base of the formation supports the interpretation of unconformable basal contacts even though the unit is strongly folded (Speed and Jones, 1969). It is overlain by volcanic rocks that are comagmatic with the adjacent Middle Jurassic gabbro. In the Pamlico-Lodi (WPL) and Luning-Berlin (WLB) assemblages of the Walker Lake terrane and the Gold Range assemblage (JTRgor), a coarse clastic and shallow marine unit of Jurassic age has been mapped as the Dunlap Formation (Stewart and Carlson, 1978). It lies unconformably over both Triassic and Permian rocks (Oldow, 1981), and disconformably over other Triassic and Lower Jurassic rocks. Some of the rocks mapped as Dunlap likely belong in unit Jcg, however, it is not consistently defined on the Nye, Mineral and Esmeralda county maps, and in many places rocks originally mapped as Dunlap have turned out to be a variety of other units. The Dunlap therefore has not been separated from the other Mesozoic rocks on this map at this time, but it may belong with a more regional Jcg unit that defines an important mid-Mesozoic tectonic constraint. Age Range: 213-163 Ma, Lower to Middle Jurassic.

Terranes
JO – Jungo terrane – Turbiditic Fine-grained Terrigenous Clastic Rocks
The Jungo terrane, also called the Lovelock assemblage or Fencemaker allochthon (Oldow et al., 1993), consists of complexly deformed thick basinal, turbiditic, fine-grained terrigenous clastic rocks, mainly Norian, but also as young as Pliensbachian (Upper Triassic to Lower Jurassic). It crops out in southern Washoe, Churchill, Humboldt, and Pershing counties. These rocks represent the basinal facies component of the Auld Lang Syne Group (Burke and Silberling, 1973; Lupe and Silberling, 1985). The Jungo terrane has no known basement and is structurally detached from coeval shelfal facies (Silberling et al., 1992). It is locally overlain unconformably by Middle or Upper Jurassic peritidal sedimentary rocks (Jcg) intruded by a gabbroic igneous assemblage (Silberling, 1991). Rocks included with the Jungo terrane were originally mapped as

the Grass Valley Formation in Humboldt and Pershing counties; some rocks mapped as the Happy Creek Volcanic series in Humboldt County; the Nightingale Sequence in southern Washoe County; the Osobb Formation in Churchill County; and the Winnemucca and Raspberry formations (Compton, 1960) in the Santa Rosa Range in Humboldt County. Age Range: 243-194, Middle Triassic to Lower Jurassic.

Walker Lake terrane
The Walker Lake terrane is divided into three assemblages or allochthons, not two subterranes as in earlier discussions (Silberling, oral comm., 2006). The three assemblages, *Pine Nut (WPN), Pamlico-Lodi (WPL), and Luning-Berlin (WLB),* have similar but not identical stratigraphic characteristics, and the Pine Nut assemblage has a distinct structural history. The Pamlico-Lodi and Luning-Berlin assemblages have different degrees of similar deformation, and different stratigraphic sequences in the oldest and youngest rocks. All three assemblages are structurally bounded from one another. Together, they form a southeast-vergent accretionary complex of Triassic volcanogenic rocks, in part interfingering with and overlain by an extensive Upper Triassic to Lower Jurassic carbonate platform assemblage that has intercalations of terrigenous and volcaniclastic rocks and grades upward into nonmarine terrigenous clastic and volcanogenic rocks (Silberling, 1991). The upper Paleozoic andesitic rocks originally included here are now reassigned to the Golconda terrane, overlain by the distinct Gold Range assemblage (JTRgor). The Sand Springs assemblage, originally included in the Paradise terrane (Silberling et al., 1987), also has been designated as a separate terrane and is not included here. The oldest Mesozoic rocks in this terrane containing abundant quartzose, continentally derived clastic materials are latest Triassic in age; the youngest stratified rocks are partly synorogenic deposits of late Early Jurassic and possibly younger age. Rocks in the Pamlico-Lodi and Luning-Berlin assemblages are present in numerous thrust nappes representing several major juxtaposed allochthons (Oldow, 1984a; Silberling and John, 1989; Speed et al., 1989; Silberling et al., 1992; Oldow et al., 1993).

Walker Lake terrane assemblages include:
WLB, *WPL*, *WPN*

WLB – Luning-Berlin assemblage, Walker Lake Terrane – Carbonate and Terrigenous-Clastic rocks
The Luning-Berlin assemblage is underlain by the regionally extensive Luning thrust and lies structurally below the Pamlico-Lodi assemblage (Oldow, 1984a). The Upper Triassic continental shelf sequence consists of platform carbonate rocks and shallow-marine to deltaic-clastic rocks. Minor amounts of volcanogenic rocks are interbedded with terrigenous-clastic rocks near the western margin of the assemblage (Oldow, 1984a). The upper part of this succession is a regionally extensive carbonate shelf which is conformably overlain by distal shelf clastic and carbonate rocks. These are conformably overlain by Lower to Middle Jurassic (Pliensbachian) quartz arenite and coarse-clastic rocks which grade upward into volcanogenic rocks (Oldow, 1984a). Rocks of the Luning-Berlin assemblage are involved in a complex deformational history involving first NW-SE thrusting, followed by second folds with NNW to WNW axial planes (Oldow, 1984a). The folding is constrained between Middle Jurassic and 90 Ma (Oldow, 1984a). Rocks that have been assigned to the Dunlap, Gabbs, Sunrise, Luning, Grantsville and Pablo Formations are included in this assemblage. Age Range: 231 – 163 Ma, Upper Triassic – Middle Jurassic.

WPL – Pamlico-Lodi assemblage, Walker Lake Terrane – Carbonate and Volcanogenic Rocks

The Pamlico-Lodi assemblage differs stratigraphically from the Luning-Berlin assemblage in that the Triassic carbonate sequences are interstratified with volcanic and volcanogenic rocks, not continentally derived epiclastic chert, conglomerate, sandstone, and argillite (Silberling and John, 1989; Oldow et al., 1993). The uppermost part of the sequence is a regionally extensive carbonate shelf like the Luning-Berlin assemblage. This is conformably overlain by quartz arenite and poorly sorted coarse-clastic rocks faunally dated as Lower Jurassic that grade upward into volcanogenic sedimentary and volcanic rocks (Oldow, 1984a). The Pamlico-Lodi assemblage has a polyphase folding history similar to the Luning-Berlin assemblage that was caused by NW-SE directed thrusting that displaced the rocks tens of kilometers toward the southeast (Oldow, 1984a). Compared with the Luning-Berlin assemblage to the east, however, rocks of the Pamlico-Lodi assemblage manifest much more shortening from this first-deformation of southeast-directed tectonic transport (Speed et al., 1989). This assemblage is exposed in Churchill, Mineral, and northern Nye counties. It includes rocks mapped as Dunlap, Excelsior, Gabbs, Sunrise, Luning and Pablo Formations. Age Range: 243 – 163 Ma, Middle Triassic through Middle Jurassic.

WPN – Pine Nut assemblage, Walker Lake Terrane – Volcanogenic, Carbonate and Clastic Rocks

This assemblage is made of Upper Triassic basinal-marine volcanic and carbonate rocks overlain by Lower Jurassic fine-grained, marine siliciclastic and tuffaceous sedimentary rocks and by partly nonmarine sandstone, coarse clastic rocks, and volcanic rocks of late Early Jurassic and younger age. This assemblage has stratigraphic similarities to the Luning-Berlin and Pamlico-Lodi assemblages, but shares only part of their late Mesozoic structural history and is separated from them by the linear trace of the northwesterly trending Pine Nut fault (Oldow, 1984a; Silberling et al., 1992). Structurally, the rocks are involved in only a single phase of tight to isoclinal folds with NNW striking axial planes, and no major internal thrust faults are known (Oldow, 1984a). The Pine Nut assemblage crops out in southern Washoe, Lyon, Douglas, Carson, and Mineral counties, and includes rocks originally mapped as the Excelsior formation, the Peavine Sequence, and other metasedimentary and metavolcanic rocks. Age Range: 231-163 Ma, Upper Triassic to Middle Jurassic.

QM – Quartz Mountain terrane – Orthoquartzite, Feldspathic Sandstone and Volcanic Rocks

The Quartz Mountain terrane, of unknown Mesozoic or Paleozoic age, is distinguished lithologically by the association of orthoquartzite with feldspathic sandstone and(or) volcanic rocks. Other rock types include metapelite, dolomite, and locally derived coarse clastic rocks (Silberling and John, 1989). This structurally disrupted mass is intricately intruded by and structurally brecciated with igneous rocks in the Lodi Hills. The structures that bound the intrusive rocks are thought to post-date the fault or faults on which the sedimentary rocks of the Quartz Mountain terrane were originally emplaced (Silberling and John, 1989). Exposures in the La Plata Quadrangle mapped as the Mountain Well sequence, have here been assigned to the Quartz Mountain terrane (John and Silberling, 1994). These rocks are exposed in Churchill and northern Nye counties. Age Range: 213-144 (?), Jurassic?

SAS - Sand Springs terrane – Basinal Volcanogenic Rocks and Carbonate Turbidites
The Sand Springs terrane is a highly deformed, thick, mainly basinal volcanogenic package of rocks at least partly of early Mesozoic age and possibly having affinities with rocks of the Black Rock-Jackson terrane (Silberling, 1991). The presumably oldest Mesozoic rocks are volcanogenic and carbonate turbidites interbedded with mudstone which grade upward into interbedded basinal carbonates and volcanogenic rocks containing Late Triassic faunas (Oldow, 1984a). Elsewhere, interbedded carbonate, volcanic and volcanogenic rocks are assigned an Early to Middle Jurassic age and represent relatively shallow-marine to subaerial deposition (Oldow, 1984a). Although structural relations in the Sand Springs terrane are locally complicated by later, Cenozoic deformation, the rocks appear to have been involved in major NW-SE shortening between the Early Jurassic and 80 Ma (Oldow, 1984a). The rocks of the Sand Springs terrane crop out in southern Washoe, Pershing, Churchill, Mineral, and northern Nye counties. Age Range: 243-163 Ma, Middle Triassic through Middle Jurassic.

BRJ – Black Rock–Jackson terrane – Basinal, Island Arc, Carbonate and Volcanogenic Rocks
This composite terrane includes Upper Paleozoic to mid-Triassic oceanic-basin and island-arc rocks in isolated exposures in northwestern-most Nevada originally assigned to the Black Rock terrane and Upper Triassic to mid-Jurassic volcanogenic and volcanic rocks of the Jackson terrane in the same region. These rocks crop out in southern Washoe, Humboldt and Pershing counties. Parts of the Black Rock terrane can be interpreted as the base of the Jackson terrane, but they are generally structurally juxtaposed throughout the region (Russell, 1984; Silberling et al., 1987; Jones, 1990; Wyld, 1990). Rocks of this terrane have affinities with correlative rocks in the Eastern Klamath and northern Sierra terranes. Age Range: 360-163 Ma, Mississippian to Middle Jurassic.

PALEOZOIC ROCKS AND TERRANES
The interpretation of Paleozoic rocks in Nevada has had a long and colorful history that is almost as interesting as the rocks themselves. Paleozoic rocks in Nevada are grouped into six categories that include stratigraphic sequences and lithologic assemblages, and three accreted terranes. These groupings were chosen to best represent the similarities and differences among different rock units.

- In the eastern third of the state, the *Carbonate Shelf sequence* includes Cambrian through Permian rocks and their metamorphosed equivalents. While these rocks have seen significant post Paleozoic disruption in places, the regional pattern of these rocks is one of either continuous conformable or disconformable sequences. Major unconformities are not part of this sequence.
- The *Foreland Basin assemblage* is an Upper Devonian through Lower Pennsylvanian siliciclastic sequence deposited on the western part of the Carbonate Shelf sequence. There may be unconformities within the Foreland Basin assemblage, but much of the sequence is conformable or disconformable, and lithologies above and below any breaks are similar, making them difficult to identify.
- The *Siliciclastic Overlap assemblage* is a Pennsylvanian through Lower Triassic sequence of siliciclastic and carbonate rocks sitting above a major unconformity on the Foreland Basin assemblage, Lower Paleozoic rocks of the Slope assemblage, the Basin assemblage, the Nolan Belt and the Dutch Flat terrane. Its sparse regional distribution but

consistent stratigraphic (and structural) position makes it an important regional tectonic constraint. Lower Triassic rocks of the Siliciclastic Overlap assemblage only are exposed in southwestern and south-central Nevada.

- In a north-south belt in the east-central part of the state, Ordovician through Lower Mississippian rocks are grouped into the *Slope assemblage*. In places parts of this assemblage are in conformable depositional contact with Carbonate Shelf sequence rocks, and fairly coherent stratigraphic sequences can be defined. In most places, these rocks are imbricated in thrust sheets with rocks of both the Carbonate Shelf sequence and the Basin assemblage. The lithologies of the Slope assemblage reflect deeper slope and basin depositional settings.
- Rocks of the *Basin assemblage* are exposed in a belt trending southwest and south from northeastern Nevada towards Esmeralda County. These Ordovician through Devonian rocks are characteristic of deep marine paleogeographic settings and include both sedimentary rocks and occasionally their mafic volcanic substrate. Apart from fragments of basaltic rocks, no basement is preserved with these rocks, and they are structurally emplaced over other generally coeval rocks. In many places they are intimately imbricated with Slope assemblage rocks, and in some places they are imbricated with Carbonate sequence rocks. While biostratigraphic evidence indicates that these rocks range from Lower Ordovician through Devonian, few stratigraphic sequences can be defined within these strongly deformed rocks. The amount of displacement experienced by the rocks in this assemblage is unknown and likely highly variable.
- A belt of lower Paleozoic rocks with strong affinity to the North American continental margin but with unusual structural characteristics forms a discrete belt west and northwest of displaced rocks of the Slope and Basin assemblages, and is here named the *Nolan Belt*. They are different from the other Paleozoic rocks in a number of important ways that warrant distinction as a separate group. These rocks have structural characteristics of an accreted terrane, that is, they exhibit polyphase deformation, but have stratigraphic ties to North America that suggest they have not traveled great distances laterally from the continental margin. The two principal characteristics of the Nolan belt of rocks are lithologically they define a region of outer shelf and slope Cambrian and Ordovician rocks, originally deposited in a more proximal position to the Carbonate Shelf sequence than the rocks of the Basin assemblage, some of which now lie structurally to the east of this belt, and unlike rocks of the Basin or most of the Slope assemblage, they are stratigraphically attached to their Cambrian to Precambrian Quartzite basement.

Two Paleozoic terranes are included, in addition to the Black Rock terrane described in the Mesozoic section which also contains some Paleozoic rocks. These terranes represent groups of rocks that have a range of ages and lithologies, but share structural or tectonic characteristics that indicate they have a common structural history that is distinct from the history of adjacent rocks. Some of these rocks may be displaced only tens of kilometers from their places of origin, while others may be displaced by thousands of kilometers. The rocks in these terranes also have tectonic histories distinct from the rocks of the continental margin prior to the time of their accretion. The terranes were accreted by a combination of translational and compressional movement leading to large steeply dipping fault zones and many imbricate slices of deformed rocks along the boundaries between these terranes and the continental margin.

- The *Golconda terrane* is a strongly deformed group of Upper Devonian through Permian deep basinal sedimentary, distal shelf clastic, volcaniclastic and volcanic rocks. The only basement known for the Golconda terrane is slivers of Mississippian to Permian ocean floor mafic and ultramafic rocks interleaved with the deep marine sedimentary and clastic rocks. It is structurally emplaced over Pennsylvanian and Permian rocks of the Siliciclastic Overlap assemblage.
- The Upper Devonian or younger *Dutch Flat terrane* is represented by the Harmony Formation, feldspathic sandstone long thought to be Cambrian. It is unconformably overlain by Pennsylvanian rocks of the Siliciclastic Overlap assemblage providing an upper age limit. Its contacts with adjacent rock units are structural. It has a unique structural history, and unique lithologic characteristics. Its origin and mode of emplacement remain unknown.
- Finally, the Paleozoic rocks of the *Black Rock-Jackson terrane* exposed in northwestern most Nevada have stratigraphic and structural affinities with coeval rocks in the eastern Klamath Mountains. These rocks were accreted to other Mesozoic rocks in Nevada during Jurassic and(or) Cretaceous time.

Carbonate Shelf sequence

In the eastern third of the state, the *Carbonate Shelf sequence* includes Precambrian through Permian rocks and their metamorphosed equivalents. While these rocks have seen significant post Paleozoic disruption in places, the regional pattern of these rocks is one of either continuous conformable or disconformable sequences. Major unconformities are not part of this sequence, although minor ones are. The Carbonate Shelf sequence rocks are principally carbonate and dolomite, with lesser amounts of shale, sandstone, quartzite and other clastic rocks typical of middle inner shelf to platform margin depositional environments. Metamorphic equivalents are also present in Cambrian through Devonian rocks and are included here as well. Two clastic units, the Eureka quartzite (Ocq), and the Lower Permian siltstone and sandstone (Psc) are also part of this sequence, the former serving as an important marker horizon in the Ordovician rocks, and the latter indicating a period of extended subaerial deposition during the Early Permian across the region. The area of the exposure of the Carbonate Shelf sequence of rocks generally defines the extent of the Paleozoic continental shelf, although locally this area has been significantly modified as the result of post Paleozoic tectonism. The Cambrian through Devonian sequence of shelf rocks can be broken out reasonably well according to the depositional sequences discussed in Cook and Corboy (2004), which is similar to, but provides more detail than the groupings used in Stewart and Carlson (1978). Units DSc and SOc are not uniformly broken out across their area of exposure. In some places Unit DSc is lumped with Unit SOc, in other places Unit SOc is lumped with Unit Oc. The resulting local differences in the stratigraphic section are largely an artifact of the map units, but may locally be caused by the irregular distribution of these units.

Units included the Carbonate Shelf sequence are:
Pc, Psc, PlPc, lPc, Mc, Dc, Dcd, DSc, SOc, Ocq, Oc, Cc, DOcm, Ocqm, OCcm, and DCc.

Pc - Cherty Limestone, Dolomite, Shale and Sandstone

These Permian rocks include cherty limestone, dolomite, shale, sandstone, bioclastic limestone and phosphatic limestone exposed in Elko, White Pine, Lincoln and Clark counties. This unit includes rocks mapped as the Phosphoria, Grandeur, Park City Group, Gerster Limestone, Plympton, Kaibab Limestone, Toroweap and the Coconino Formations. Unit Pc is disconformably overlain by Triassic unit TRmt in scattered places in eastern and southern Nevada. It depositionally overlies unit Psc. It matches closely with unit Pc from Stewart and Carlson (1978). Age Range: 258-253 Ma, Middle Permian, Guadalupian.

Psc – Siltstone, Sandstone, Limestone and Dolomite
This largely siliciclastic unit of siltstone, sandstone, limestone and dolomite crops out in Elko, White Pine, Lincoln and Clark Counties. It includes rocks originally mapped as the Arcturus Formation and Rib Hill Sandstone, undivided Kaibab Limestone, Toroweap and Coconino in Clark County, the Pequop Formation, and red beds in Lincoln County. Unit Psc represents a strong influx of clastic material over the carbonate shelf during the Early Permian, presumably derived primarily from the craton to the east. It is depositionally overlain by unit Pc and sits conformably above unit PlPc. At its western and northern edges it can be difficult to distinguish from Permian clastic rocks of the Siliciclastic Overlap assemblage (Units Pacl and PlPacl). It follows closely with unit Psc from Stewart and Carlson (1978). Age Range: 286-258 Ma, Lower Permian, Wolfcampian and Leonardian.

PlPc - Limestone, Dolomite, Siltstone, Sandstone and Shale
Limestone, dolomite, siltstone, sandstone and shale present in Elko, White Pine, Lincoln and Clark Counties. This unit represents Pennsylvanian (mostly upper) and Lower Permian rocks. The Ely Limestone (lPc) is not broken out from this unit in eastern White Pine County, nor is there an equivalent lower Pennsylvanian carbonate distinguished in Clark County. It includes unnamed Pennsylvanian and Lower Permian limestone and sandstone beds in Lincoln County, the Bird Spring Formation and Callville Limestone in Clark County, and the Riepe Spring and Ely Limestones (grouped) in White Pine County. This unit sits depositionally below Unit Psc and above the Ely limestone (lPc). Where the Ely limestone is not differentiated in southern Nevada it sits directly on Mississippian carbonate (Mc) and in White Pine County it rests on undivided Chainman, Pilot and Joanna (shown as either Unit lPMcl or MDcl). Age Range: 320-268 Ma, Pennsylvanian to Lower Permian.

lPc - Bioclastic Limestone
Lower Pennsylvanian bioclastic limestone is present in Nye, Elko, Eureka, White Pine and Lincoln Counties, and is generally referred to as the Ely Limestone. Where rocks were mapped separately as the Moleen Formation, a ledgy gray limestone, they are included here. It is not mapped separately from Unit PlPc in most of White Pine County. Throughout most of the area of exposure it sits conformably or disconformably beneath unit PlPc and depositionally above unit lPMcl. In southern Nye County this unit includes the Tippipah Limestone. In a north-south trending belt starting at the north end of the Pancake Range in Nye County and continuing north up through the Diamond Mountains along the Eureka-White Pine County border, lower Pennsylvanian limestone is overlain unconformably by clastic rocks of the Siliciclastic Overlap assemblage (Pacl, PlPacl). North of the Diamond Mountains, where lower Pennsylvanian carbonate is not recognized separately, the coeval facies are grouped with Unit lPMcl. Unit lPc is primarily Pennsylvanian, but in places contains Late Mississippian fossils as well. Age Range: 320-296 Ma, Lower Pennsylvanian, Morrowan to Desmoinesian.

Mc – Limestone
This Mississippian Limestone is present in southern Nye, Lincoln, and Clark Counties. This unit includes parts of the Bird Spring Formation, the Monte Cristo Limestone, the Callville Limestone, some rocks referred to the Joana, Mercury and Bristol Pass Limestones, and the Rogers Spring Limestone. It generally sits depositionally above Devonian carbonate rocks and beneath Pennsylvanian carbonate and clastic rocks. In the Meadow Valley Mountains in southern Lincoln County it is also shown sitting on a thin horizon of Pilot Shale and overlain by a thin Mississippian clastic unit assigned to lPMcl. Age Range: 360-320 Ma, Mississippian.

Dc - Limestone and minor Dolomite
Upper Devonian Unit Dc includes generally cliff-forming thin-to thick-bedded limestone. These rocks are mainly shallow-water subtidal, intertidal, and supratidal deposits formed on a broad inner carbonate shelf (Stewart, 1980). The Devils Gate and Guilmette Formations in northern Nevada are the principal units, and the Sultan Limestone, Tor and McMonnigal limestones are included from the southern part of the state. It is overlain (usually disconformably) by the Pilot shale of Unit MDcl except in southernmost Nevada where it is overlain by Mississippian carbonate (Mc). It depositionally overlies Lower and Middle Devonian Unit Dcd. In a few places, such as southern Nevada and parts of Eureka County, regional mapping did not distinguish the Middle and Upper Devonian section from the Lower Devonian section, and all of the Devonian is included in Unit Dc. Rocks mapped as the Simonson would fit into this depositional sequence (sequences 9 and 10) according to Cook and Corboy (2004), but they are not differentiated from the underlying dolomites in White Pine or Elko Counties, so they are all included in that unit (Dcd) here. This unit crops out in Clark, Elko, Eureka, Lincoln, Nye and White Pine Counties. Age Range: 387-367 Ma, Middle to Upper Devonian.

Dcd – Dolomite, Sandstone and Limestone
Lower and Middle Devonian dolomite, sandstone and limestone crop out over the same area as Unit Dc. Its primary formations are the Nevada Formation and the Sevy dolomite, although in White Pine County, there may be some undivided Guilmette included. The Simonson dolomite is also included here as it is not differentiated in White Pine and Elko Counties. These rocks correspond to depositional sequences 6,7 and 8 of Cook and Corboy (2004). Unit Dcd is overlain by Unit Dc and is depositional on Unit DSc. In White Pine County and most of Elko County, Unit DSc is not broken out from Unit SOc, hence the Devonian dolomite sequence appears to rest directly on Unit SOc. Age Range: 408-374 Ma, Lower to Middle Devonian.

DSc – Dolomite
Silurian and lowest Devonian dolomite of Unit DSc correspond with sequence 5 of Cook and Corboy (2004) and includes the Laketown and Lone Mountain dolomites and equivalent unnamed rocks. In White Pine County these rocks are grouped with the underlying Unit SOc, but otherwise are exposed in Elko, Eureka, Nye, Lincoln and Clark Counties. Disconformities and discontinuities are commonplace along both contacts (Langenheim and Larson, 1973). Unit DSc is depositionally overlain by Unit Dcd, except where these rocks are grouped with Unit Dc. In general, Unit DSc sits on Unit SOc. In Clark County and parts of Elko, Unit SOc is not differentiated from Unit Oc, and therefore DSc sits directly on Oc. In the Sulphur Spring Range, DSc overlies Unit DSt, and in the Roberts Mountains it grades laterally and vertically down into Unit DSt. The Lone Mountain Dolomite has been shown to be both primary and secondary

dolomite (Nichols and Silberling, 1977a) and therefore the boundaries mapped between Unit DSc and both underlying DSt and overlying Dcd are not primary depositional features in all cases, especially in the Roberts Mountains. Age Range: 438-394 Ma, Silurian to Lower Devonian.

SOc – Dolomite, Limestone and Shale

Dolomite, limestone and shale of the Ely Springs Dolomite and Hanson Creek Formation are the main formations included in this unit. Many of these rocks are not assigned to a formation. A large section of the Carbonate platform from latest Ordovician through Early Devonian time is represented by dolomitic rocks. They commonly look similar, have poor biostratigraphic control, and thus are not always well differentiated on the County maps. Additionally, not all of the dolomite is primary, and thus boundaries between secondary dolomite and other rock units have been misinterpreted as primary stratigraphic boundaries, further confusing the stratigraphy of the lower Paleozoic shelf (Nichols and Silberling, 1977a). Rocks in this unit correspond to sequence 4 of Cook and Corboy (2004). This unit includes rocks deposited immediately above the Eureka quartzite, but disconformably below the Lone Mountain and Laketown dolomites, hence it includes the uppermost Ordovician and the Silurian. Rocks included in Unit SOc that are mapped as the Hanson Creek Formation are overlain by the Roberts Mountains Formation of Unit DSt in the northern and western part of the exposure area. The SOc rocks mapped as Hanson Creek Formation can be difficult to distinguish from Unit DSt and Unit Ot. In general Unit SOc is not broken out from Unit Oc in Clark County, and thus unit DSc rests directly on Unit Oc. In Lincoln and Nye Counties Unit SOc sits directly on the Eureka quartzite (Ocq) and is overlain by the Laketown dolomite (DSc). In southern Nye County, rocks mapped as Ely Springs are grouped with the Eureka Quartzite as Unit Ocq. In White Pine and eastern Elko County, the Eureka quartzite is not broken out, and unit SOc sits directly on Unit Oc, which includes the quartzite. Also in White Pine and eastern Elko counties, Unit DSc is not broken out from Unit SOc, so SOc is overlain directly by Unit Dcd. In the northern and western areas of exposure, Unit SOc is overlain by Unit DSt of the Slope assemblage. Age Range: 458-408 Ma, Upper Ordovician to Silurian.

Ocq – Quartzite

Because of its importance as a stratigraphic marker horizon, the Eureka Quartzite is depicted on this map wherever it is mapped separately from the Ordovician carbonate shelf rocks. It represents depositional sequence 3 of Cook and Corboy (2004). It is not broken out from the rest of the Ordovician (Unit Oc) in White Pine or Clark Counties, but is shown in Elko, Eureka, Nye and Lincoln counties. Rocks mapped as the Ely Springs Dolomite are included with the Eureka Quartzite in southern Nye County. The Eureka Quartzite sits on the Pogonip Group of the Carbonate platform (Oc), and is overlain by either the Hanson Creek Formation or the Ely Springs dolomite (Unit SOc). Age Range: 478-448 Ma, Middle to Upper Ordovician.

Oc - Limestone, Dolomite and Quartzite

Limestone, Dolomite and Quartzite of the Ordovician Carbonate platform is present in Nye, Lincoln, Elko, Eureka, Lander, White Pine, Esmeralda, and Clark counties. This unit is primarily Ordovician in age but does include some Upper Cambrian rocks. The Pogonip Group is the most common name used, but it also includes the Antelope Valley Limestone. It also includes the Ely Springs dolomite in Clark County, and it includes the Eureka Quartzite in White Pine and Clark

Counties. Unit Oc corresponds to depositional sequence 2 of Cook and Corboy (2004). Where broken out, Unit Oc is overlain by Unit Ocq. Otherwise it is depositional under Unit SOc, or in southern Nye and Clark Counties, it is overlain directly by DSc where Unit SOc is not differentiated. Unit Oc depositionally overlies Unit Cc. Age Range: 525-448 Ma, Upper Cambrian to Upper Ordovician.

Cc – Dolomite, Limestone and Shale
This unit includes dolomite, limestone and shale in southern and eastern Nevada. The Bonanza King and Carrara Formations are the primary formations in southern Nye county; the Dunderberg shale in northern Nye and Lincoln counties; the Hamburg Dolomite in Eureka county; the Nopah Formation in southern Nye and Esmeralda counties; the Patterson Pass and Pioche Shales, the Chisholm and Highland Peak Formations, and the Lyndon Limestone in Lincoln County; the Pole Canyon Limestone and the Lincoln Peak and Windfall Formations in northern Nye County; and undifferentiated limestone and dolomite in Lincoln, Clark, White Pine, Eureka, northern Nye and Elko counties. This unit is conformably overlain by the Ordovician Shelf rocks (Unit Oc), and is depositional on the underlying Precambrian-Cambrian quartzite of Unit CZq. Age Range: 570-505 Ma, Cambrian.

Undivided and Metamorphosed Carbonate Shelf sequence rocks
DCc - Dolomite and Limestone
Lower Paleozoic dolomite and limestone present in southeastern Lincoln and Clark counties are grouped together into Unit DCc. The lower Paleozoic section is too thin to split out into individual units, and the structure is too complex in these rocks to accurately portray the individual units at this scale. In part of Clark County these rocks are referred to the Goodsprings Dolomite. In the Mormon Mountains of Lincoln County these rocks are overlain by Mississippian carbonate (Mc). In Clark County in the Spring Mountains, they are overlain by the Devonian Sultan Limestone (Dc). Age Range: 590-374 Ma, Cambrian to Middle Devonian.

DOcm - Dolomite and Graphitic Marble
Dolomite marble and graphitic marble in the Ruby Mountains, East Humboldt Range and Wood Hills in Elko County that rests above the Eureka Quartzite (Ocqm) is included in this unit. Age Range: 505-374 Ma, Ordovician to Devonian.

Ocqm – Metaquartzite
The metamorphosed Eureka Quartzite is shown separately in the Ruby Mountains, East Humboldt Range and Wood Hills in Elko County, and serves as a valuable marker horizon for the thick sequence of metamorphosed lower Paleozoic shelf rocks. Age Range: 478-448 Ma, Middle to Upper Ordovician.

OCcm - Calcite Marble
Calcite marble that rests below the Eureka quartzite marker horizon in the Ruby Mountains, Wood Hills, and Pequop Mountians in Elko County is included in this unit. Age Range: 590-438 Ma, Cambrian to Ordovician.

Foreland Basin assemblage

The Foreland Basin assemblage is a sequence of Upper Devonian through Lower Pennsylvanian siliciclastic and carbonate rocks deposited disconformably on older Paleozoic rocks of the Carbonate Shelf sequence. The boundaries between the Foreland Basin assemblage and coeval rocks of the Carbonate Shelf sequence migrated east and west as a result of the changing tectonic and depositional settings during this time. Disconformities may be part of this assemblage but are often difficult to identify in these rocks, some of which have limited biostratigraphic control and consist largely of reworked siliciclastic rocks. The primary distinction with coeval rocks to the east in the Carbonate Shelf sequence is the principally siliciclastic nature of the units, with a secondary carbonate component. In addition, the source of much of the siliciclastic component is interpreted to be material from the west as well as from the east. Because of significant Mesozoic and younger structural disruption of these rocks, original stratigraphic relations can be difficult to determine.

Units included in the Foreland Basin assemblage are:
lPMcl, MDcl

lPMcl – Shale, Siltstone, Sandstone and Conglomerate

This unit of shale, siltstone, sandstone, quartzite and conglomerate crops out across all of eastern Nevada, generally east of 116° west longitude, and somewhat farther west in the southern half of the state. It includes rocks mapped as the Chainman shale in Elko, northern Nye, and Lincoln counties, the Diamond Peak Formation in northern Nye, Elko, Eureka, and White Pine counties, the Scotty Wash Quartzite in Lincoln County, the Eleana Formation in Nye County and undivided sedimentary rocks in Eureka and Lincoln counties. These rocks are Upper Mississippian and Lower Pennsylvanian. Clastic and carbonate rocks mapped in Elko County, including undivided Moleen and Tomera Formations are also grouped here. Unit lPMcl also may include lower Mississippian rocks, overlapping with the MDcl unit where they have not been clearly differentiated. In some places the Chainman shale is time transgressive into the Diamond Peak Formation, and in other places they are different coeval facies, based on limited biostratigraphic data. Where possible, younger siliciclastic rocks have been separated from the older sequence that includes the Pilot Shale and Joana Limestone because of significant differences in the character of the rocks, and the importance of the older unit (MDcl) in signaling the onset of tectonic activity affecting the continental margin. Unit lPMcl is overlain conformably or disconformably in the eastern part of its exposure by carbonate rocks of units PlPc and (or) lPc. In the northern and western parts of its exposure it is overlain unconformably by Pennsylvanian and Permian clastic rocks of the Siliciclastic Overlap assemblage (Pacl or PlPacl). Assignment of siliciclastic Pennsylvanian units to either Unit lPMcl or the unconformably overlying PlPacl is challenging unless biostratigraphic data are available and outcrop observations reveal the presence of the unconformity such as in Carlin Canyon (Dott, 1955). Unit lPMcl sits either conformably or disconformably above Unit MDcl. Age Range: 352-296 Ma, Upper Mississippian to Lower Pennsylvanian.

MDcl – Siltstone, Limestone, Shale and Sandstone

This unit of siltstone, limestone, shale and sandstone crops out across all of eastern Nevada, generally east of 116° west longitude. It includes rocks mapped primarily as Pilot shale, Joana limestone and Chainman shale and their equivalents. This also includes the Tripon Pass limestone in Elko County, the Cockalorum Wash Formation in northern Nye County, the Mercury and Bristol Pass Limestones in Lincoln County, and some of the rocks mapped as Monte Cristo Limestone in Clark County. While it may be desirable to separate out the different lithologies, they are not differentiated well at this regional map scale. The Chainman, Joana and Pilot are grouped in White Pine County, and the Joana and Pilot are grouped in Elko County. The Pilot shale is sitting depositionally (both conformably and disconformably) on Upper Devonian carbonate rocks (Dc) and signals a major change in the depositional setting across most of the carbonate platform which has long been attributed to the onset of deformation attributed to the Antler Orogeny. The Pilot is generally recognized as carbonaceous shale, overlain by the cliff-forming Joana limestone. Siliciclastic quartz-bearing grit and chert and quartz sand and siltstone in a calcareous matrix become increasingly common as the section turns into the Chainman Shale and other equivalent siliciclastic rocks. The sequence is interrupted by disconformities in a number of places, but structural disruption and poor age control hinder determination of the nature of the contacts between the distinct lithologies. Unit MDcl is overlain by Unit lPMcl, but there places where the age and distinction between the units is poorly constrained. In southernmost Nevada in Clark and southeastern White Pine counties, Devonian carbonate is overlain by Mississippian carbonate (Mc) with little or no intervening Pilot shale equivalent and few overlying siliciclastic rocks with western-derived source material. North and west of the area of exposure of Unit MDcl, fault-bounded slivers of Upper Devonian and Lower Mississippian platform margin and slope facies rocks with siliciclastic horizons have been grouped into unit MDst and separated from unit MDcl. Rocks of Unit MDcl are Upper Devonian and Lower Mississippian, although they includes some younger Mississippian rocks in places. Age Range: 374-352 Ma, Upper Devonian and Lower Mississippian.

Siliciclastic Overlap assemblage
The Siliciclastic Overlap assemblage is a discontinuous sequence of Pennsylvanian, Permian and Triassic siliciclastic and carbonate rocks deposited with marked unconformity, usually with a basal conglomerate, over variably deformed Paleozoic rocks of the Dutch Flat terrane (DF), the Nolan Belt (OCtd, Ctd), the allochthonous Basin and Slope assemblage rocks (DOs, DOts, DSt, MDst) and the Foreland Basin assemblage (lPMcl, MDcl). The exposures are scattered over a wide area as far west as the Osgood Mountains in Humboldt County and as far east as the HD Range in northeastern Elko County. Exposures are present as far south and west as Candelaria in Mineral County and as far southeast as the Hot Creek Range and possibly into the Pancake Range in eastern Nye County. Outcrops are always spotty and discontinuous regionally, but the geologic relations are always very consistent. The regionally significant characteristics of this group are (1) it sits with marked unconformity on deformed older Paleozoic rocks, (2) it is a mixed sequence of siliciclastic and carbonate rocks, commonly with locally derived conglomeratic horizons, (3) it has internal disconformities and unconformities, and (4) it is structurally overlain by rocks of the Golconda terrane (GC) along a low angle structure in many places. The oldest rocks of the assemblage are mid-Pennsylvanian or Atokan, and the youngest rocks of the sequence are Upper Permian, except in southeastern Nevada where the Permian rocks are overlain disconformably by Lower Triassic rocks (Unit TRcl is described above under Mesozoic Sedimentary rocks). All of the section is not present at all exposures; there is a significant unconformity within the section between Lower and Upper Permian rocks such that the younger Permian rocks are frequently sitting directly on deformed lower Paleozoic rocks. Everywhere except where the rocks sit on the Foreland Basin assemblage, the unconformity is

pronounced and the time gap ranges from as large as Permian overlying Cambrian to as small as Middle Pennsylvanian over Devonian or possibly Early Mississippian. Where the rocks overlie the Foreland Basin assemblage, in some areas the unconformity is very marked, such as in Carlin Canyon (Dott, 1955; Trexler et al., 2004), but the lithologies are similar above and below the unconformity -- making it difficult to distinguish in areas of poor exposure, and the time gap is much smaller, with Middle or Upper Pennsylvanian rocks sitting on Lower or possibly Middle Pennsylvanian rocks (Trexler et al., 2004). Because this assemblage overlaps so many different rocks with distinct tectonic histories, it serves as an important regional age constraint for a number of major Paleozoic tectonic events (Theodore et al., 2003). This assemblage is broken into three units that include rocks that are Lower Triassic (TRcl), mostly Upper Permian (Pacl), and rocks that are Pennsylvanian to Lower Permian (PlPacl). Disconformities or unconformities are present between each of these units. In places where this assemblage has not been broken into separate units it is grouped into Unit PlPacl.

The units included in the Siliclastic Overlap assemblage are:
TRcl, Pacl, PlPacl. See above under Mesozoic Sedimentary Rocks for description of TRcl.

Pacl - Antler Sequence Sandstone, Conglomerate, Siltstone, Limestone and Carbonaceous Limestone
The sandstone, limestone, calcisiltite and siltstone in this sequence is mapped in Elko, Mineral, Humboldt, Lander, Eureka, White Pine and northern Nye and Esmeralda counties. Included in this unit are the Carbon Ridge Formation in Eureka and White Pine Counties, parts of the Carlin sequence of Coats (1987) and the sandstone and siltstone of Horse Mountain in Elko County, the Edna Mountain formation in Humboldt and Elko counties, the Antler Peak limestone in Humboldt County, the Garden Valley Formation in Eureka County, The Carbon Ridge Formation in Eureka and White Pine Counties, and the Diablo Formation in northern Nye, Mineral and Esmeralda counties. In the Candelaria area south of Mina Unit Pacl rests unconformably on deformed Ordovician through Devonian Basin and Slope assemblage rocks (DOs, DOts) and is overlain by the Lower Triassic Candelaria Formation (TRcl). In the Toiyabe Range it sits unconformably on deformed Cambrian through Ordovician rocks of the Nolan Belt (OCtd). In the Simpson Park Mountains and the Sulphur Spring Range it rests unconformably on Ordovician Slope assemblage rocks (DOts). In the Diamond Mountains it rests unconformably on the Ely Limestone (lPc). In the Eureka area, Unit Pacl unconformably overlies the Ely Limestone (lPc) and the Diamond Peak formation (lPMcl) and is unconformably overlain by Cretaceous conglomerate (Kcg). Near Golconda it unconformably overlies Unit PlPacl. In the Adobe Range in Elko County it rests on Foreland Basin assemblage rocks (lPMcl, MDcl) and Unit PlPacl, and in the Snake Mountains and HD Range of northeast Nevada it lies unconformably on lower Paleozoic slope and basin assemblage rocks (DOs, Ss, DOts) and on older Overlap assemblage rocks (PlPacl). Age Range: 286-253 Ma, Permian.

PlPacl - Antler Sequence Conglomerate, Sandstone and Limestone
Sandstone, limestone and conglomerate in this unit represents rocks that are stratigraphic sequences that include both Pennsylvanian and Lower Permian rocks, and also sections that have not been broken out regionally into older and younger Pennsylvanian and Permian units. The Antler Sequence rocks are present in Humboldt and Lander Counties and include the Antler Peak limestone, the Highway limestone, the Battle Formation or Battle Mountain Conglomerate, and

the Etchart formation. The Brock Canyon Formation of undifferentiated Pennsylvanian-Permian age is in the Cortez Mountains in Eureka County and the siliciclastic and carbonate Strathearn Formation is exposed in Elko County (Theodore et al., 2003). Scattered remnants of conglomerate, sandstone, siltstone and limestone in Nye County, and unnamed limestone and dolomite in Elko County are also included. In the Hot Creek Range in Nye County, these rocks are associated with Lower Triassic rocks that match the Candelaria formation in age. In the Pancake Range, these rocks are sitting on the Ely Limestone (lPc). In the Toquima Range, the Pennsylvanian Wildcat Peak formation sits unconformably on Slope and Basin assemblage rocks (DOts). In the Monitor Range and in Lander County this unit sits unconformably on the Lower Paleozoic Basin assemblage rocks (DOs). At Battle Mountain this unit includes the Antler Peak Limestone and the Battle Formation which sits unconformably on both the Harmony Formation, which is the Dutch Flat terrane (DF), and the Valmy Formation of Basin assemblage Unit DOs. At Edna Mountain near Golconda and in the Osgood Mountains it sits unconformably on Precambrian-Cambrian Quartzite (CZq) and Cambrian phyllite and shale (Ctd) of the Nolan belt, as well as on Basin and Slope assemblage rocks (DOs, DOts). In the Cortez Mountains of northern Eureka County it sits unconformably on Basin and Slope assemblage rocks (DOs, DOts). In the Adobe Range and the Sulphur Spring Range it sits unconformably on Pennsylvanian Foreland Basin rocks (lPMcl) (Trexler et al., 2004). In northern Elko County in the Bull Run and Copper Mountains, it sits unconformably on strongly deformed Cambrian to Ordovician rocks of the Nolan Belt (OCtd). In the Snake Mountains and the HD Range, the Pennsylvanian Quilici formation sits unconformably on the Basin and Slope assemblage rocks (DOs, DOts, Ss) and is unconformably overlain by the Permian Overlap assemblage rocks (Pacl). In far northeastern Nevada, Upper Paleozoic rocks around Contact are very poorly known, but are similar to the Overlap assemblage rocks recognized in the HD range, and are thus included in this group. Age Range: 315-253 Ma, Middle Pennsylvanian to Upper Permian.

Slope assemblage

Slope assemblage rocks consist of limestone, argillaceous limestone, carbonaceous shale, calcareous siltstone, shale, argillite, quartzite and bedded chert, with siliciclastic and conglomeratic horizons of chert clasts and quartz in places. The environment of deposition of this group of rocks is actually quite varied -- in a number of cases the rocks are more typical of a ‘basin’ environment. Slope facies rocks are difficult to identify because of their varied lithologic characteristics. These varied characteristics are the result of both complex ocean chemistry variations through time, composition of rocks of adjacent margin(s), and tectonic setting of the margin. These factors all affect composition of sediment deposition along the slope of a continental margin through time. Nonetheless, a distinct group of rocks that were not deposited completely in either a carbonate shelf environment or an ocean basin environment can be identified in Nevada. These rocks tend to be present in regions of steep gradients along a margin, and thus do not commonly have the lateral extent that is seen in Carbonate shelf rocks or Basin facies rocks (albeit deformed). In Nevada, lower Paleozoic Slope assemblage rocks are critical components of two major geologic features and thus worthwhile to differentiate from other rocks. The slope of the margin was the locus of disruption during mid-Paleozoic (and later) tectonism and these rocks were intimately involved in rifting, folding and thrusting of the margin during the Paleozoic and again during the Mesozoic. Many of these rocks are also compositionally ideal hosts for sediment-hosted gold deposits (Cook and Corboy, 2004) and have a known gold endowment of over 100 million ounces (Christensen, 1993) giving them global economic significance. In a number of cases slope facies rocks are not currently well broken out at a regional map scale from Basin assemblage rocks, but commonly, these units can be distinguished at least to a first order. Three Slope assemblage rocks units are designated on this map, and two other units of slope affinity are treated separately under the *Nolan Belt*. Units MDst and DOts always occur in structurally bounded settings and cannot be tied to a specific place on the continental margin, except to say that they formed in proximity to a continental margin, or possibly on the slope of an oceanic feature such as a seamount, as they contain significant horizons of siliciclastic material derived from a cratonal setting, and common turbiditic horizons suggesting significant sediment transport down a slope. Although units MDst and DOts are structurally bounded and have complex deformational histories involving imbricate thrusting, they usually contain definable stratigraphic sequences and important marker horizons (Finney et al., 1993; Cluer et al., 1997; Noble et al., 1999), and tend to be only locally altered or metamorphosed from mineralizing systems or igneous rocks. Unit DSt is mapped as depositional on Ordovician and Silurian rocks of the Carbonate Shelf sequence in a number of places, and it is also involved in imbricate thrusting with Basin assemblage and Shelf sequence rocks. While great progress has been made in biostratigraphic dating of these rocks, in many areas further work is required to separate similar looking, different age rocks that have long been assumed to be part of a stratigraphic sequence, but are actual structural imbrications of varied ages.

Units included the Slope assemblage are:
MDst, DSt, DOts

MDst – Shale, Graywacke, Siltstone, Chert, Conglomerate and Limestone
Carbonaceous shale, black chert and argillite, graywacke, chert-pebble conglomerate, and detrital limestone are the primary lithologies described from all of the rocks assigned to this unit, representing a mixed slope and basinal facies. On other maps these rocks have been included in a variety of units including the foreland basin and Devonian siliceous and transitional rocks. Mapping and new biostratigraphic data gathered in the last 30 years have shown that many of these rocks mapped as Devonian also contain Lower Mississippian rocks, making it difficult to distinguish them from known lithologically similar Lower Mississippian rocks, and therefore they are included together on this map. This unit is structurally bounded, although a stratigraphic link to underlying Slope assemblage rocks is possible. These rocks are imbricated with units DOs, lPMcl, Oc, Ocq, DSt, Dc, and MDcl. Whether there is a definable Devonian through Early Mississippian sequence within this unit is unknown, but is suggested in the Carlin-Piñon Range (Smith and Ketner, 1978). The Slaven Chert first described in the Shoshone Range (Gilluly and Gates, 1965) is black chert with carbonaceous shale beds 4 to 10 feet thick, limy brown-weathering sandstone as much as 4 ft thick with coarse fragments of chert, shale, greenstone and limestone, graywacke, feldspathic siltstone, and brown-weathering limestone 2 to 20 ft thick and contains Late Devonian radiolarians (Boundy-Sanders et al., 1999). The Mississippian Water Pipe Canyon Formation is a similar formation with basal medium-grained graywacke with interlayered black, carbonaceous shale, chert-pebble conglomerate, and bedded chert passing upward into sandstone layers with black, well-rounded quartz and a black, pyritic, phosphate- and barite-bearing, argillaceous matrix that are interlayered with black, platy, quartz siltstone and fine-grained graywacke interbeds. It contains Early Mississippian radiolarians (Peters et al., 2003). In the HD Range in northeastern Elko County, an undated light-gray weathering, brittle, black shale, structurally underlies the other thrust sheets and was referred to the Chainman by

Riva (1970). In the Windermere Hills a fissile black argillite with sporadic interbeds of quartz-chert arenite is poorly exposed with variable dips suggesting complex structure (Oversby, 1972). In the Cockalorum Wash quadrangle along the Eureka-Nye County boundary, a pale yellow brown organic detrital limestone contains quartz and chert grains locally interbedded with and succeeded upward by light-colored siliceous mudstone, claystone and siltstone. The basal limestone contains mixed Devonian and Mississippian faunas, a thin chert from a higher zone has Osagean radiolarians (Hose, 1983). In the northern Adobe Range, this unit is recognized as dark siliceous rocks; shale, argillite and bedded chert. They are faulted and folded with sparse collections of Kinderhookian and Fammenian radiolarians and conodonts (Ketner and Ross, 1990). The Webb Formation in the Carlin-Piñon Range is a gray siliceous mudstone with black to gray tan-weathering dense limestone in lenses near top (Smith and Ketner, 1978). The argillite of Lee Canyon is a black siliceous argillite with a little black chert and a very little conglomerate and sandstone near the top (Smith and Ketner, 1978). In the Sulphur Spring Range, the Bruffey sequence (Carlisle and Nelson, 1990) is a black chert pebble to boulder conglomerate and well-bedded gritty limestone, chert and limestone conglomerate, gray limy shale, and minor sandstone. Smith and Ketner (1978) describe the same rocks as gray limestone, sandy limestone, chert and chert pebble conglomerate. The Woodruff Formation from the same area is described by Carlisle and Nelson (1990) as a gray fissile shale, dolomitic siltstone and black and brown bedded chert. Smith and Ketner (1978) describe the Woodruff as dark gray to black siliceous mudstone and chert, lesser amounts of shale, siltstone, dolomitic siltstone, dolomite and limestone. In the Shoshone Range, pale-red to pale-brown weathering, platy, silty dolomite interbedded with black chert in the basal 50 feet of rocks referred to the Pilot Shale by both Gilluly and Gates (1965) and Wrucke (1974) is included here. In the southern Independence Range, this unit is a fine-grained limestone, bedded chert, shale, conglomerate, and prominent ledges of limy sandstone with Famennian and Frasnian (Late Devonian) conodonts (Ketner, 1998). In Welches Canyon northwest of Carlin, this unit is gray to black limestone, fine grained and thin to thick bedded with common sand and silt-size clasts of quartz and chert grains. It also contains pebbles and cobbles of chert, and interlayered chert and siliceous shale as much as 50 feet thick (Evans, 1974). In the Snake Mountains, the unit is dark carbonaceous limestone apparently overlain by a light-gray, siliceous platy siltstone. Other outcrops that belong with MDst, but are not presently broken out from other units include the Pinecone sequence in the Toquima Range (Coles and Snyder, 1985), and gold-bearing chert (Theodore, T., oral comm., 2006) mapped as the Rodeo Creek formation, in the Carlin area. In places, Devonian and Mississippian rocks are still grouped with units DOs and DOts. Age Range: 408-352. Devonian to Lower Mississippian.

DSt - Platy Limestone, Dolomite and Chert

Platy limestone, dolomite and chert are characteristic of the auriferous Roberts Mountains Formation in Nye, Elko, Eureka and Lander Counties and of the Masket shale, Gatecliff formation and Diana and Caesar Canyon limestones in northern Nye County. This unit sits with depositional contact over the Hanson Creek Formation of unit SOc of the Carbonate Shelf sequence (Unit Oc in southern Nevada), and is also structurally imbricated with Carbonate Shelf sequence rocks and other Slope and Basin assemblage rocks (Units DOs, DOts, MDst, and Oc) across its area of exposure. In the Carlin area, rocks assigned to the Popovich Formation and the Bootstrap limestone (Jory, 2002; Berger and Theodore, 2005) are also included. In the Monitor Range, the Roberts Mountains, and the Sulphur Spring Range this unit is mapped as stratigraphically overlain by Unit DSc. To what extent this “overlying” dolomite is truly a stratigraphic unit as opposed to an alteration product of this unit (Nichols and Silberling, 1977a) is unclear. A stratigraphic contact with unit MDst in the Carlin area is possible based on recent mapping (Theodore et al., 2003; Berger and Theodore, 2005). Age Range, 438-387 Ma, Silurian to Lower Devonian.

DOts - Calcareous Shale, Siltstone, Chert, Quartzite and Greenstone
Calcareous shale, siltstone, sandstone, chert, quartzite and greenstone in the Vinini Formation in Lander, Eureka, Elko and northern Nye counties and the Clipper Canyon sequence in the northern Toquima Range are the core formations of this unit. Difficulties in distinguishing distinct paleogeographic settings within the non-Carbonate Shelf sequence Ordovician rocks are discussed in Finney and Perry (1991) and Finney et al. (1993). On a regional scale, the distinction between this unit and rocks traditionally mapped as Valmy formation (DOs) is the preponderance of shale and siltstone of cratonal derivation that is present in the Vinini rocks but less common in the Valmy rocks. Both rock units contain bedded chert, massive quartzite and greenstone(Finney and Perry, 1991) in many places. Many Ordovician rocks grouped here likely formed in a basinal rather than slope setting, but the presence of more common siliciclastic horizons of shale, siltstone and sandstone distinguish them as a regional grouping from the Ordovician Basin assemblage rocks. Whether this is a function of distinct paleogeographic settings of coeval units as interpreted by early workers, or is actually an age distinction of older (Valmy) versus younger (Vinini) Ordovician rocks as suggested more recently for at least the Roberts Mountains (Finney et al., 1993) remains to be determined on a regional scale. Silurian, Devonian and even lower Mississippian rocks are intimately imbricated with the Ordovician rocks of this group (Coles and Snyder, 1985; Noble and Finney, 1999). The distinction between DOts and DOs as currently mapped on a regional scale is ambiguous in many places. Distinguishing the numerous occurrences of Devonian and Silurian rocks that are embedded within this unit on a regional scale would significantly enhance our understanding of the complex structural history of these rocks. These rocks are everywhere in structural contact with other Paleozoic rocks including Units lPMcl, Pacl, Dc, MDst, DSt, DSc, and Dcd. Stratigraphic correlation has been made between rocks of the Vinini Formation and the Carbonate Shelf sequence in Nevada (Finney and Perry, 1991) on the basis of occurrence of quartzite that is coeval with the shelf unit Ocq. While this does suggest a connection between the Ordovician rocks of this composite unit and North America, the quartzite was deposited along a 1,000 mile length of the margin and thus does not constrain the rocks of unit DOts to deposition along a specific section of the margin. These rocks are unconformably overlain sporadically by Units Pacl and PlPacl, and post Paleozoic cover rocks. Age Range: 505-360 Ma, Ordovician to Devonian.

Basin assemblage
Basin assemblage rocks range from latest Cambrian through Devonian in age and represent rocks that formed primarily in a basin or lower continental-slope setting. Common rock types include chert, argillite, feldspathic siltstone and shale, quartzite, greenstone and minor carbonate. Because of complex deformation in all of these rocks, it has been difficult to subdivide them into Ordovician, Silurian, and Devonian units, and they have generally been grouped together into larger units that represent a wide range of age and lithologic characteristics on regional maps. Distinguishing the numerous occurrences of Devonian, Silurian and Ordovician rocks that are

embedded within this unit on a regional scale would significantly enhance our understanding of the complex structural history of these rocks. These rocks are all displaced from their place of origin, and the amount of displacement relative to the continental margin is unknown, although in every place that structural studies have been done, these rocks show evidence of regional east-directed transport (Evans and Theodore, 1978; Oldow, 1984b; Peters, 1997a, b, c). Thick beds of massive quartzite are common in these rocks and the timing of their deposition corresponds to at least some of the influx of quartz sand along the continental shelf suggesting a connection to the North American craton (Miller and Larue, 1983). Quartz sand was deposited along much of the western margin of North America more than once during the Ordovician (Ketner, 1986; Finney and Perry, 1991; Gehrels et al., 2000).

Units included in the Basinal assemblage are:
DOs, Ss

DOs - Shale, Chert, Quartzite, Greenstone and Limestone
Unit DOs consists of shale, chert, argillite, quartzite, greenstone and minor limestone included in the Valmy Formation in Eureka, Humboldt, Lander and Pershing counties, unnamed Devonian to Ordovician mudstone, shale, chert, siltstone, and gray quartzite in Elko County, unnamed Ordovician to Devonian slate, chert, limestone and sandstone in Mineral County, unnamed Ordovician to Devonian rocks in Eureka County, some rocks mapped as the Palmetto Formation in Esmeralda County, and the Sonoma Range formation in the Sonoma Range in Humboldt County. The distinctions between these rocks and rocks of the slope assemblage (DOts) are (1) a more complex and varied history of deformation (2) less well defined internal stratigraphic characteristics which may be a function of structural complexity (3) fewer shale, siltstone and sandstone interbeds (4) less carbonate, and (5) in the Roberts Mountains at least, the Ordovician rocks are older than the slope assemblage Ordovician rocks. Like Unit DOts, no basement is preserved with these rocks, making it difficult to determine where they were originally laid down, and how far they have been transported. This unit includes uppermost Cambrian, Ordovician, Silurian and Devonian rocks imbricately faulted and folded together. In a few places, Silurian rocks are defined regionally and broken out separately (Ss), but for the most part they are included in this unit. Likewise, significant exposures of Devonian rocks have been included in Unit MDst, but many more are not differentiated from this unit. A great variety of depositional settings are present in ocean basins, and this diversity is represented in these rocks (Watkins and Browne, 1989). While these rocks share a common deformation history indicative of east-directed transport from folding and thrusting along regional structures, in different areas of Nevada, these rocks have been subject to additional distinct tectonic events during the Paleozoic and the Mesozoic resulting in significant spatial variability in the structure of these rocks (Evans and Theodore, 1978; Oldow, 1984b) Age Range: 525 – 360 Ma, Upper Cambrian to Devonian.

Ss - Feldspathic Sandstone, Siltstone, Shale and Chert
In the HD Range in northeastern Elko County, the Noh Formation was described by Riva (1970) and consists of a basal dark gray chert and light gray shale, light-brown weathering siliceous and tuffaceous siltstone and shale, and tan- and light-brown-weathering thin-bedded siltstone, sandstone and minor shale. It contains a large and diagnostic Wenlockian (Lower Silurian) graptolite fauna, and is partly coeval with the base of the Roberts Mountain Formation (DSt)

which also has a conspicuous basal chert ledge. The similar age Elder Sandstone in Lander and Eureka counties was named for moderately cemented sandstones exposed in the Shoshone Range (Gilluly and Gates, 1965). It is primarily a fine-grained silty sandstone, sandy siliceous and tuffaceous shale, and thin, play, light brown chert. Much of the sandstone and siltstone is notably feldspathic including abundant angular fragments of K-feldspar, and has reported interbedded rhyolite in places (Theodore, T., oral comm., 2006). It is grouped with DOs or DOts in many places. Its unusual lithologic characteristics warrant a separate grouping where it can be separated from these units (Noble et al., 2000). Zircon studies have suggested that the feldspathic source material for these rocks was not located adjacent to the Nevada part of the continental margin, but is derived from a source either farther to the north or in Mexico (Gehrels et al., 2000). Likewise, tuffaceous source material for the shale described in the Noh Formation is not known from the Nevada continental margin of this time. Like most other rocks of the Slope and Basin assemblages, Unit Ss is everywhere in structural contact with other Paleozoic rocks. It is structurally imbricated with Units DOs, DOts, and MDst. Whether these rocks have traveled a significant distance either toward or along the margin as discrete tectonic blocks or as sediment transported in offshore turbidity systems is not known, but no basement is preserved with them, and they are unconformably overlain only by post Paleozoic cover. Age Range: 438 – 408 Ma, Silurian.

Nolan Belt

A belt of lower Paleozoic rocks with strong affinity to the North American continental margin but with unusual structural characteristics form a discrete belt west and northwest of displaced rocks of the Slope and Basin assemblages. Earlier maps included these rocks in either ‘Transitional’ or ‘Siliceous’ groupings. They are different from the other Paleozoic rocks in a number of important ways that warrant distinction as a separate group. These rocks have structural characteristics of an accreted terrane, that is, they exhibit polyphase deformation, but have stratigraphic ties to North America that suggest they have not traveled great distances laterally from the continental margin. The origin of the name of this group is for T.B. Nolan, whose early paper defined many of these rocks as part of an important ‘geanticline’ during the later Paleozoic long before such concepts had any grounding in modern tectonic understanding (Nolan, 1928), and prior to recognition of the magnitude of displacement that has affected adjacent Paleozoic rocks and terranes. The distinguishing characteristics of the Nolan belt of rocks are (1)lithologically they define a region of outer shelf and slope Cambrian and Ordovician rocks, originally deposited in a more proximal position to the Carbonate Shelf sequence than the rocks of Units DOs or DOts, which now lie east, or inboard of many exposures of Units OCtd and Ctd; (2) Unlike rocks of Units DOts, DOs or Ss, they are stratigraphically attached to their Cambrian to Precambrian Quartzite basement (CZq), otherwise exposed only much farther to the east; (3) they have a varied and complex structural history that in at least some cases clearly involves multiple pre-Pennsylvanian deformation events with an earlier east vergent deformation superimposed with a younger west-vergent event (Means, 1962; Oldow, 1984b; Ehman, 1985; Crafford and Grauch, 2002); (4) Like rocks of the Basin, Slope, and Foreland Basin assemblages they are unconformably overlain by Pennsylvanian and younger rocks of the Siliciclastic Overlap assemblage, constraining the age of much of their deformation to pre mid-Pennsylvanian; (5) rocks of the Nolan belt have been much more deeply buried than coeval and lithologically similar rocks that crop out farther east, as witnessed by the metamorphic character of the slates, phyllites and schists, and by the Conodont Color Alteration Index of the rocks (Crafford and

Harris, 2005). Two units are included in this group exclusively, Units OCtd, and Ctd. The basement rocks are treated separately because they are common to the base of both the Nolan belt and the Carbonate Shelf sequence.

Units included in the Nolan Belt are:
OCtd, Ctd

OCtd - Shale, Chert, Phyllite, Quartzite and Limestone
Shale, Phyllite, Quartzite, Schist and Limestone included in this unit have been mapped as the Broad Canyon and Crane Canyon sequences in Lander County, the Palmetto formation in Esmeralda and Nye Counties, the Van Duzer limestone in northern Elko counties, and many other unnamed and locally named rocks. These rocks are strongly deformed, although the nature of the deformation is variable across the belt (Oldow, 1984b) and not well understood regionally. This unit is usually shown both in fault contact with adjacent Units Ctd and Czq and gradational with them. Unit Pacl of the Siliciclastic Overlap assemblage is shown unconformably deposited on this unit in Wall Canyon of the Toiyabe Range in Nye County. In a few cases this unit is a stratigraphic continuation from Unit Ctd, but in most places it represents undifferentiated rocks of both Cambrian and Ordovician age that overlap with Unit Ctd, or whose age is poorly constrained. Age Range: 590 – 438 Ma, Cambrian and Ordovician.

Ctd – Phyllite, Schist, Shale, Thin-bedded Limestone, Chert and Siltstone
Shale, thin-bedded limestone, phyllite, hornfels, quartzite, chert and siltstone are typical of this Cambrian to Lower Ordovician unit which exhibits regional metamorphism suggesting significant burial depths have heated and recrystallized many of these rocks. This unit includes rocks mapped as the Bull Run dolomite in northern Elko County, the Crane Canyon sequence in the Toiyabe Range, some polygons mapped as Dunderberg shale, and the Swarbrick Formation in northern Nye county, the Emigrant Formation in southern Nye and Esmeralda counties, the Mule Spring Limestone in Esmeralda County, the Preble Formation in Humboldt and Pershing counties (Madden-McGuire, 1991), the Paradise Valley chert in Humboldt County, and the Schwin Formation in the Shoshone Range in Lander County. In most exposures this unit sits transitionally above the Cambrian-Precambrian quartzite unit Czq. In places this unit includes Lower Ordovician rocks, and in other places it is transitional into Unit OCtd. This unit is also in structural contact with Units DOs, DOts, Oc, OCtd, CZq, the Golconda terrane (GC), and the Dutch Flat terrane (DF). In the Osgood Mountains (Madden-McGuire and Marsh, 1991; Boskie and Schweickert, 2001; Crafford and Grauch, 2002), the Bull Run Mountains (Ehman, 1985), the Toiyabe Range (Means, 1962) and the Miller Mountain area (Oldow, 1984b) these rocks exhibit complex polyphase deformation. At Edna Mountain near Golconda in Humboldt County, these rocks are unconformably overlain by both Units Pacl and PlPacl of the Siliciclastic Overlap assemblage. Age Range: 590 – 505 Ma, Cambrian to Lower Ordovician.

Terranes
GC – Golconda terrane – Basinal, Volcanogenic, Terrigenous Clastic and minor Carbonate Rocks
The Golconda terrane is composed of deformed and imbricated thrust slices of upper Paleozoic rocks including deep-marine, pelagic and turbiditic, carbonate, terrigenous clastic and volcaniclastic rocks, radiolarian chert and argillite, and pillow basalt (Silberling et al., 1992).

While the terrane is characterized by a great diversity of rock types, all rocks are strongly deformed with an east-vergent fabric, a distinguishing characteristic of this terrane (Miller et al., 1982; Brueckner and Snyder, 1985; Stewart et al., 1986; Murchey, 1990; Jones, 1991a). It crops out in a long sinuous belt, up to 100 miles wide in places. Southwest of Mina, the belt trends east from the California border to just north of Tonopah, and then bends north-south to the west of Longitude 117° to about 50 miles north of Winnemucca, where it bends again, sharply to the east north of Tuscarora with significant exposures eastward and to the northern border of the state. Outcrops of the Golconda terrane are present in Mineral, Esmeralda, northern Nye, Churchill, Elko, Humboldt, Lander and Pershing counties. It includes some rocks originally mapped as Banner and Nelson formations in Elko County, rocks originally mapped as the Excelsior Formation in Mineral and Esmeralda Counties later assigned to the Black Dyke and Mina Formations by Speed (1977b) the original Havallah and Pumpernickel Formations (Muller et al., 1951; Silberling and Roberts, 1962; Roberts, 1964), later revised to structural sequences (Stewart et al., 1977a; Stewart et al., 1986; Murchey, 1990; Theodore, 1991, 1994) in Elko, Humboldt, Lander and Pershing Counties, the Inskip sequence in Pershing County, the Mitchell Creek formation in Elko County, the Pablo Formation in northern Nye County, and the Schoonover Formation (see GChr) in Elko County.

In all of the places where rocks of the Golconda terrane were originally believed to form a stratigraphic sequence, detailed mapping and biostratigraphic analysis with radiolarians and conodonts has demonstrated that it is characterized by complex imbrications of rocks ranging from uppermost Devonian through Middle Permian in age (Stewart et al., 1977a; Miller et al., 1984; Holdsworth, 1986; Murchey, 1990; Jones, 1991b). In Pershing County, the Golconda terrane is unconformably overlain by Triassic volcanic rocks of the Koipato sequence (TRkv) which form the stratigraphic base of the Humboldt assemblage (TRc, JTRs). In Mineral and Esmeralda Counties, it is unconformably overlain by the Gold Range assemblage (JTRgor) of mainly nonmarine, terrigenous clastic and volcanogenic Upper Triassic and younger rocks. Elsewhere in northern and southwestern Nevada, it is structurally overlain by Mesozoic accreted terranes. Across the length of its exposure from the Independence Mountains north of Elko to the Candelaria region south of Mina, the base of the Golconda terrane has a remarkably consistent structural emplacement relationship with adjacent rocks. It commonly sits on a low angle structure above Pennsylvanian and Permian rocks of the Siliciclastic Overlap assemblage. In places where these rocks are missing, it is faulted directly onto the nearby lower Paleozoic Basin assemblage or the Nolan Belt rocks, or the Harmony Formation of the Dutch Flat terrane. The type locality of this regional feature, the Golconda thrust is well exposed along Interstate 80 at Edna Mountain near the town of Golconda, and in the open pits of mines near Battle Mountain (Theodore, T., oral comm., 2006), In southwestern Nevada, the lower Lower Triassic rocks of the Candelaria Formation overlie Permian Siliciclastic Overlap assemblage rocks, and the Golconda terrane is exposed nearby, but not observable directly on top of it because of younger cover rocks. Elsewhere, the youngest age to constrain the age of emplacement is post Middle Permian. In several places, notably in the Osgood Mountains and the Toiyabe Range, it also is bounded by large steeply dipping mélange-like shear zones against older rocks of the Nolan Belt. Stratigraphic and structural studies within the terrane have broken it into locally identifiable lithostratigraphic groupings (Erickson and Marsh, 1974b, a; Murchey, 1990; Jones, 1991a) but only the Home Ranch subterrane can presently be distinguished on a regional scale (GChr). Interpretations of the size and character of the Upper Paleozoic basin where these rocks formed, and the nature of its Upper Permian or Lower Triassic accretion are as varied as the lithologic and structural characteristics of the terrane itself (see above references). Age Range: 374 – 253 Ma, Upper Devonian to Middle Permian.

GChr – Golconda terrane- Home Ranch subterrane- Limestone, Basalt, Chert and Volcaniclastic Rocks

The Home Ranch subterrane of the Golconda terrane shares similar structural characteristics with the rest of the Golconda terrane, but is has more specific age and lithologic features. It is restricted to Mississippian in age (usually Lower), and consists of shallow water, fossiliferous limestone, black chert, basalt and volcaniclastic rocks. Olistostromal debris flows of basalt and limestone indicative of steep paleotopography are a distinguishing characteristic (Jones, 1991a). The depositional setting for this subterrane can be interpreted as a seamount. It includes rocks in Elko County mapped as the Banner and Nelson formations, at least parts of the Inskip Formation in Pershing County, the Goughs Canyon formation in the Osgood Mountains and similar rocks in the Hot Springs Range in Humboldt County, and likely includes Mississippian limestone in the San Antonio Mountains in northern Nye County. To what extent these rocks have a history distinct from other rocks of the Golconda terrane is unclear. They are present structurally in a position outboard or west of most other exposures of the Golconda terrane, and they are separated in the northern part of the state from some other exposures of the terrane by the Nolan belt. Age Range: 360 – 320 Ma, Mississippian.

DF – Dutch Flat terrane – Feldspathic Sandstone, Shale and Turbiditic Limestone

The Dutch Flat terrane is the Upper Devonian or younger Harmony Formation. It consists of coarse graded feldspathic sandstone and siltstone with rare quartzose turbiditic limestone interbeds that have yielded sparse reworked late Devonian and post Ordovician conodonts and conodont fragments (Jones, 1997a; Ketner et al., 2005). The controversial history of the age of the Harmony is discussed in Jones (1997). The Dutch Flat terrane crops out in Humboldt, Lander and Pershing counties. In the Hot Springs Range, it is structurally bounded to the northwest by the Golconda terrane and on the southeast by Unit DOs of the Basin assemblage. In the Osgood Mountains it has been structurally dismembered into mélange blocks that are part of an upper Paleozoic matrix of argillite and shale associated with the Golconda terrane (Jones, 1991b). In the Sonoma and East Ranges, much of it is mélange-like in character and it has additionally been folded and faulted with Triassic and Ordovician rocks(Silberling, 1975). At Battle Mountain(Doebrich, 1994; Theodore et al., 1994), it is structurally adjacent to rocks of the Basin assemblage (DOs), but it is unconformably overlain by the Pennsylvanian rocks of the Siliciclastic overlap assemblage, providing a critical constraint on the timing of its accretion to adjacent rocks. Because it is structurally bounded everywhere its stratigraphic relation to other units in Nevada remains uncertain, although it has lithologic features in common with rocks of the Golconda terrane and the lower Paleozoic Basin assemblage (Ketner et al., 2005). In places it has west vergent folding throughout, while in other places the formation is characterized by east vergent folding. Interpretations of the origin of the rocks of the Harmony and its tectonic history (Smith and Gehrels, 1994; Gehrels et al., 2000; Ketner et al., 2005) have yet to fully explain its significant role in the mid-Paleozoic tectonism that affected Nevada. Its varied structural characteristics and enigmatic lithology suggest that this terrane is far traveled and has had a complex history of interaction with other Paleozoic rocks in Nevada. Age Range: 374-320 Ma, Upper Devonian to Mississippian.

PRECAMBRIAN AND OTHER ROCKS

Precambrian to Lower Cambrian clastic rocks form the base of the Carbonate Shelf sequence in eastern and southern Nevada. They also form the stratigraphic base of the rocks of the Nolan Belt. They are part of a large sequence of Precambrian rocks that represent the original rifted margin of western North America. They rest unconformably over Proterozoic basement that is only exposed in southernmost Nevada.

Other rocks include a breccia unit of mixed breccias that identifies locally disrupted rocks, a gneiss, schist and migmatite in Elko County, the only high-grade metamorphic rock in Nevada, and ultramafic rocks including serpentine are scattered in a few places around the state adjacent to major terrane boundaries.

Precambrian to Lower Cambrian Clastic Rocks

Units included in Precambrian to Lower Cambrian Clastic Rocks are:
CZq, CZqm, Zqs

CZq - Crossbedded Quartzite, Siltstone and Phyllite

This unit is primarily crossbedded quartzite, siltstone and phyllite. These Precambrian to earliest Cambrian strata are scattered over much of central and eastern Nevada, and form the base of the Phanerozoic part of the continental margin stratigraphic section. They include the Campito, Deep Spring, Harkless and Poleta Formations and the Reed Dolomite in Esmeralda County, the Gold Hill Formation in northern Nye County, unnamed quartzite and shale in White Pine County, the Osgood Mountains quartzite in Humboldt County, the Prospect Mountain Quartzite in northern Nye, Lincoln, Eureka and Elko counties, unnamed quartzite and shale in Lander and Clark counties, and the Stirling Quartzite, Wood Canyon Formation, and Zabriskie Quartzite in southern Nye County. In a number of places these rocks are depositional on Precambrian Unit Zqs. In southernmost Clark County, Unit CZq is shown sitting unconformably directly on Proterozoic gneiss (Xm). In the east-central part of Nevada, this Unit is overlain depositionally by Cambrian carbonate (Cc) of the Carbonate Shelf sequence. In the Nolan Belt, these rocks are depositionally overlain by Unit Ctd. In the Osgood Mountains in Humboldt County, Pennsylvanian and Permian rocks of the Siliciclastic Overlap assemblage (PlPacl, Pacl) rest unconformably directly on the Osgood Mountains Quartzite. Age Range: 800 – 540 Ma, Upper Precambrian Z to Lower Cambrian.

CZqm – Metaquartzite

This highly metamorphosed equivalent of unit CZq crops out in the Ruby Mountains and East Humboldt Range in Elko County, in the Toquima and Monitor ranges in northern Nye County, and at the northern tip of the White Mountains in Mineral and Esmeralda Counties. In the Ruby Mountains it is transitional into unit OCcm, and in the White Mountains it is transitional in to Unit OCtd. Age Range: 800 – 540 Ma, Upper Precambrian Z to Lower Cambrian.

Zqs - Quartzite, Siltstone, Conglomerate, Limestone and Dolomite

Limestone, quartzite, dolomite, siltstone, conglomerate and metamorphic rocks crop out in the southeastern, east central and northeastern regions of the state as part of Unit Zqs. It forms the Proterozoic base of the continental margin stratigraphic section. This unit includes the Johnnie

Formation in southern Nye and Lincoln counties, schist in Elko County, the McCoy Creek group metamorphic rocks in Elko and White Pine counties, and the Wyman Formation in Esmeralda and southern Nye counties. This rock is overlain by Unit CZq. Its base is not exposed. Age Range: 800 – 600 Ma, Precambrian Z.

Proterozoic Basement Rocks
Units included in Proterozoic Basement Rocks are:
Ygr, Xm

Yfi – Felsic Intrusion
This porphyritic rapakivi granite is present only in Clark County where it intrudes Proterozoic Gneiss and Schist (Xm). Age Range: 1,475 – 1,425 Ma, Precambrian Y.

Xm - Gneiss and Schist
Proterozoic gneiss and schist is exposed mostly in Clark and Lincoln counties, with two small outliers in southern Nye County. Age Range: 1,765 – 1,715 Ma, Precambrian X.

Other Rocks
Units included in Other Rocks are:
br, MzTgn, Pzsp

br - Mixed Breccias including Volcanic, Thrust, Jasperoid and Landslide Megabreccia
Breccias of various origins are scattered across Clark, Nye, Lincoln, Elko, Eureka, Lander and White Pine Counties. Most are interpreted to be Tertiary in age, but they have tectonic, volcanic, and metamorphic origins, and include jasperoids, brecciated tuffs, exotic slide blocks, landslide deposits, megabreccia, thrust breccia, and debris beds. Age Range: 65 - 2.5 Ma, Tertiary.

MzTgn – Gneiss, Schist and Migmatite
In the Ruby Mountains and East Humboldt Range in Elko County this unit is granodiorite and quartz monzonite gneiss, granitic to dioritic gneiss, biotite and muscovite schist, quartzitic schist, quartzite, calc-silicate rocks, marble and migmatitic Oligocene granodiorite, Jurassic and Cretaceous granite and Precambrian quartzite. Age Range: 213 – 24.6 Ma, Jurassic to Lower Tertiary.

Pzsp - Ultramafic Rocks and Serpentine
Ultramafic rocks are present in very small belts or lenses in a few places across the state. In the Candelaria Hills along the Mineral-Esmeralda County boundary they crop out in a thrust complex that overlies the Candelaria Formation (TRcl). At Willow Spring at the southern end of the Toquima Range south of Manhattan serpentine is exposed again adjacent to the Candelaria Formation and deformed lower Paleozoic rocks (OCtd). A few small outcrops also are present on the east side of the Toquima Range near Belmont adjacent to lower Paleozoic rocks. In the Toiyabe Range in Nye County, scattered outcrops of serpentine form a narrow north-south trending belt adjacent to the Golconda terrane (GC), deformed lower Paleozoic rocks (OCtd, Ctd), and the Siliciclastic Overlap assemblage. An early Triassic conodont was recovered near the serpentine near Marysville Canyon, although the Candelaria Formation does not show on the map in this area. All of these exposures of ultramafic rocks are in a similar relative tectonic

position above deformed lower Paleozoic rocks and the Siliciclastic Overlap assemblage, and below the structurally overlying Golconda terrane. A narrow belt of serpentine and gabbro is exposed at the northern edge of the Golconda terrane in the Hot Springs Range in Humboldt County. In this case, the ultramafic rock is structurally above the Golconda terrane, and beneath the overlying Mesozoic Jungo terrane (JO). The age of the ultramafic rocks is likely Upper Paleozoic or Triassic. Age Range: 360 – 213 Ma, Upper Paleozoic – Triassic.

MAP REFERENCES

References used in editing the geologic map in addition to the 1978 State Map and the individual county maps are shown in the 'Refs' attribute column of the geology layer. The codes and references used are listed here and shown in complete form in the References section.

Map Reference Code	Reference
Abase	Henry, Chris, unpublished radiometric database of Nevada, Nevada Bureau of Mines and Geology
Barnes and others, 2001	(Barnes et al., 2001)
Cohen, 1980	(Cohen, 1980)
CONO	Harris, Anita, ConodontSamples.shp, this map.
Ehman, 1985	(Ehman, 1985)
GSA SP 163	(Silberling, 1975)
Heidrick, 1965	(Heidrick, 1965)
Lovejoy, GSA Bull 70 p. 539	(Lovejoy, 1959)
Means, 1962	(Means, 1962)
Miller et al., 1984	(Miller et al., 1984)
NBMG FS Map 12	(Henry, 1996)
NBMG FS Map 14	(Jones, 1997b)
NBMG FS Map 21	(Miller et al., 1999)
NBMG FS Map 4	(Mueller, 1993)
NBMG Map 104	(Martin and Naumann, 1995)
NBMG Map 143	(Theodore et al., 2003)
NBMG Map 35	(Fritz, 1968)
NBMG Map 97	(Carlisle and Nelson, 1990)
NBMG OFR 03-4	(Thorman et al., 2003)
NBMG OFR 04-9	(Thompson et al., 2002)
Neff, 1969	(Neff, 1969)
Oldow, 1984	(Oldow, 1984a)
OSS, 1993	(Oldow et al., 1993)
Oversby, 1972	(Oversby, 1972)
PandW, 1978	(Poole and Wardlaw, 1978)
Peters et al, 2003	(Peters et al., 2003)
Riva, 1970	(Riva, 1970)
Rowley, 1980	(Rowley, 1980)
SandS, 1989	(Speed et al., 1989)
Sayeed, 1973	(Sayeed, 1973)

Speed-Diablo-77	(Speed et al., 1977)
Stewart, 1980	(Stewart, 1980)
Thurber, 1982	(Thurber, 1982)
USGS B 1162-B	(Ketner and Smith, 1963)
USGS B 1312-P	(Wells and Elliott, 1971)
USGS B 1439	(Coats et al., 1977)
USGS B 1988-D	(Ketner et al., 1993)
USGS GQ-1117	(Evans, 1974)
USGS GQ-1174	(Erickson and Marsh, 1974a)
USGS GQ-1307	(McKee, 1976a)
USGS GQ-1710	(John and Silberling, 1994)
USGS GQ-1721	(Anderson and Hintze, 1993)
USGS GQ-1758	(Miller et al., 1995)
USGS GQ-1759	(Hintze and Axen, 1995)
USGS GQ-656	(Gilluly, 1967)
USGS I-1028	(Smith and Ketner, 1978)
USGS I-1410	(Hose, 1983)
USGS I-1578	(Ekren and Byers, 1985)
USGS I-1866	(Loucks et al., 1989)
USGS I-1902	(Ketner and Evans, 1988)
USGS I-2081	(Ketner and Ross, 1990)
USGS I-2082	(Ketner, 1990)
USGS I-2097	(Smith et al., 1990)
USGS I-2394	(Wallace, 1993)
USGS I-2409	(Whitebread, 1994)
USGS I-2629	(Ketner, 1998)
USGS I-612	(Nolan et al., 1971)
USGS I-667	(Evans and Ketner, 1971)
USGS I-793	(Nolan et al., 1974)
USGS MF-1877-J	(John, 1987)
USGS MF-2062	(Silberling and John, 1989)
USGS MF-2154-A	(Greene et al., 1991)
USGS MF-2327	(Shawe, 2002)
USGS OFR 03-236	(Sloan et al., 2003)
USGS OFR 68-260	(Stewart and McKee, 1968)
USGS OFR 84-644	(Coats et al., 1984)
USGS OFR 91-429	(Theodore, 1991)
USGS OFR 94-664	(Doebrich, 1994)
USGS PP 575-D, p56-63	(Stewart and Palmer, 1967)
USGS PP 592	(Silberling and Wallace, 1969)
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Wyld, 2002	(Wyld, 2002)

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