24200067

Dear Bob, here's a closer to final version - what do you think? I'd appreciate your criticisms - don't know if your silence about the last version is intense disapproval or not!

Regards,
Elizabeth

I'm heading out to Nevada the 11/6 can't wait to get out of here!!

THRUST EMPLACEMENT OF SCHOONOVER SEQUENCE,
NORTHERN INDEPENDENCE MOUNTAINS
NEVADA

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INTRODUCTION

Deep-water sedimentary rock assemblages of both upper and lower Paleozoic age are exposed in the northern Independence Mountains, Nevada (Fig. 1). The lower Paleozoic rocks are equivalent to units present in the Roberts Mountains allochthon (Fig. 1) that was thrust eastward onto the continental shelf in the latest Devonian - earliest Mississippian Antler Orogeny (Churkin and Kay, 1967; Roberts and others, 1958; Silberling and Roberts, 1962; Roberts, 1964; Poole and Sandberg, 1977; Stewart and Carlson, 1979. The time of (final?) emplacement of these rocks in the Independence Mountains, however, is believed to have occurred in post Mississippian(?) times (Kerr, 1962; Churkin and Kay, 1967).

The erosion of highlands formed by thrusting during the Antler Orogeny shed a large volume of clastic sediments eastwards into a foredeep basin (Poole and Sandberg, 1977)(Fig. 1), but across much of north-central Nevada, the eroded Roberts Mountains allochthon is depositionally overlain by Mississippian to Permian shallow water sequences (overlap assemblage of Roberts and others, 1958). These shallow water sequences were overridden in the Permo-Triassic by the Golconda allochthon, which contains an Upper Mississippian to Permian deep-water assemblage of rocks called the Havallah sequence (Roberts, 1964; Silberling and Roberts, 1962; Silberling, 1975; Speed, 1979) (Fig. 1). More poorly dated Mississippian and younger(?) rocks of the Schoonover Formation described by Fagan (1962) in the Independence Mountains, Nevada have been correlated to the Havallah sequence (Stewart and Carlson, 1978) (Fig. 1). In the Independence Mountains, however, these rocks were believed to depositionally overlie deformed rocks of the Roberts Mountains allochthon (Churkin and Kay, 1967). Because of poorer constraints on the age range of the Schoonover Formation and its presumed stratigraphic rather than structural relationship with underlying rocks, its correlation to the allochthonous Havallah sequence remained unclear.

We present preliminary paleontologic, sedimentologic, and structural data collected by the Stanford Summer Field Geology class in 1979 that suggest at least a portion of the Schoonover Formation (here called the Schoonover sequence) is time-equivalent to the Havallah sequence and that the Schoonover is ~~bound beneath~~ rests on by a major thrust fault. This thrust fault juxtaposes paleogeographically distant, time-equivalent and older deep-water rocks to shallow-water rocks in post-Late Permian time and thus is possibly equivalent to the Golconda Thrust.

GEOLOGIC SUMMARY

Upper Paleozoic "overlap assemblage" sequences

Deformed Ordovician and orthoquartzite, argillite, siltstone and chert correlative to the Valmy Formation of the Roberts Mountains allochthon is unconformably overlain by massive sedimentary breccia and conglomerate along a spectacular unconformity exposed at several locations near Schoonover Creek (Fig. 2) (Churkin and Kay, 1967).

The basal conglomerate consists mostly of angular blocks and boulders of orthoquartzite derived from the underlying Valmy equivalent rocks. Finer-grained sandstones above the conglomerate consist primarily of quartz and chert grains with lesser amounts of lithic fragments of quartzite, siltstone and argillite. Most of the finer-grained rocks overlying the basal conglomerate have been silicified, greatly hindering the determination of original lithologic characteristics in the field. Partially silicifed limestone in the sequence just above the basal conglomerate along Schoonover Creek has yielded Upper Mississippian brachiopods and conodonts (Fig. 2) (Coats, 1980). As this non-marine to shallow marine sequence unconformably overlies deformed lower Paleozoic deep water rocks correlative to those in the Roberts Mountain allochthon, we tentatively correlate the overlying sequence to the overlap assemblage of Roberts and others (1958).

On the east side of the range, Ordovician Valmy equivalent rocks are in high angle fault contact with tightly folded lower Paleozoic miogeoclinal carbonate rocks (Fig. 2). The original relationship between the deep-water Ordovician rocks and the miogeoclinal rocks is uncertain, as the fault contact between the two units is a much younger feature (Fig. 2). We interpret the miogeoclinal rocks to have once been in an autochthonous or parautochthonous lower plate position with respect to allochthonous deep water lower Paleozoic rocks, a relationship such as that described in the ~~Seetoya~~ southern Independence Mountains ~~to the south~~ by Kerr (1962) (Fig. 1). The lower Paleozoic miogeoclinal rocks, dated as Cambrian in one locality are unconformably overlain by a sequence of conglomerate, siltstone, and limestone, the uppermost units of which contain Permian fossils (Churkin and Kay, 1967) (Fig. 2). It is presently not known whether or not the base of this sequence contains older Carboniferous rocks.

In order to expose presumed lower plate position rocks to erosion, these must either have been structurally high with respect to upper plate rocks (imbricated with them) and/or both upper and lower plate rocks must have been subject to an episode of block faulting and erosion prior to deposition of the overlying Permian rocks. Thus, although the upper Paleozoic sequence in the eastern part of the range is in a sense an "overlap assemblage" as well, it does not overlie allochthonous deep water rocks and may be younger in age than the sequence at Schoonover Creek.

Between the eastern and western "overlap-assemblage" localities, scattered exposures of chert and quartzite-grit arenite occur along the north-trending spurs between glacial cirques (Fig. 2). These rocks are commonly silicified, but their petrography indicates derivation from a quartzite-chert-argillite assemblage of rocks similar to that present in the underlying Valmy-equivalent sequence. Molds of transported brachiopods in these rocks have been dated as Late Permian (Table I).

Because of the lack of map continuity between these three upper Paleozoic "overlap assemblages" and the occasional complete silicification of these rocks (and thus the inability to compare their stratigraphy), the relationship between the three remains presently unresolved.

Allochthonous rocks of the Schoonover sequence

In contrast to the disparate assemblages of rock deposited unconformably above deformed lower Paleozoic rocks in the northern Independence Mountains, the base of the Schoonover sequence (Schoonover Formation of Fagan, 1962) is fairly continuous across the map region and is here interpreted as a thrust fault (Fig. 2). The Schoonover sequence consists of a heterogeneous assemblage of deformed deep-water sedimentary rocks that can be grossly subdivided into two parts: a lower, mostly siliceous assemblage of sedimentary rocks and greenstone units, and a structurally higher, more calcareous assemblage of sedimentary rocks with no intercalated greenstone units (Fagan, 1962).

Discontinuous greenstone units occur along or near the base of the Schoonover sequence, but the bulk of the lower part of the sequence consists of siliceous argillite and units of isoclinally folded thin bedded radiolarian chert. The axial planes of folds strike N47E and dip 67 NW. Fold axes form a girdle within this plane but most are subhorizontal (Fig. 2). Interspersed with these rocks are discontinuous units of chert pebble conglomerate, quartzose arenite, and pebbly mudstone. Lithic (chert and volcanic) greywacke, tuffaceous chert, and volcaniclastic rocks constitute minor portions of the lower part of the Schoonover sequence.

Clastic rocks within the lower part of the Schoonover sequence exhibit a wide range of compositions, with detritus indicating at least two different sources. Chert (and minor quartzite) pebble conglomerate and arenite units that contain sub-angular to well-rounded grains of strained quartz, lithic fragments of metachert, quartzite, siltstone, argillite, and very minor K-feldspar, were most likely derived from the erosion of Roberts Mountains allochthon rocks. The composition of these clastic rocks both in hand specimen and in thin section is virtually identical to that of arenite and conglomerate in the "overlap assemblages". In contrast, abundant detrital plagioclase and basaltic composition lithic fragments in some rocks and plagioclase and euhedral embayed quartz grains in tuffaceous rocks and other turbidite-deposited units indicates a volcanic source for some Schoonover clastic units

(Fig. 3). One of the thin sections examined contained evidence for derivation of detritus from both deformed sedimentary and volcanic sources.

The upper part of the Schoonover sequence, on the other hand, contains variable amounts of silty limestone turbidites, chertified silty limestone, argillite, quartzose arenite, and no greenstone units (Fagan, 1962) (Fig. 2). The composition of the calcareous turbidites clearly represents the presence of yet a third, carbonate-rich source terrane for these Schoonover units.

The Schoonover was believed to be upper Mississippian in age, based on a fossil assemblage collected from a limestone bed immediately above greenstone along Dorsey Creek (Fagan, 1962; Churkin and Kay, 1967) and on the basis of conodonts (Poole and Sandberg, 1977, p.____, fig. 2a).

We have dated nine radiolarian samples from the Schoonover sequence and these ages are listed in Table I. The oldest radiolarian sample, locality 2-6, is clearly interbedded with tuffs that occur above greenstone near the structural base of the Schoonover in the western part of the map area (Fig. 2). This particular sample is definitely as old as lowermost Mississippian and is possibly as old as latest Devonian. Our other eight samples are from ridge-forming outcrops of isoclinally folded, thinly bedded chert in the structurally lower part of the Schoonover sequence. These eight dates range from lower Mississippian to Pennsylvanian. The age progression of these dates correlates imperfectly with the sample's vertical position in the sequence, suggesting unrecognized larger-scale structures in this portion of the sequence (Table I; Fig. 2).

Because of the structural complexity of the Schoonover sequence, we do not know if the ages of the ribbon chert packages we have dated also represent the age-span of pebble conglomerate, quartzose arenite, volcanogenic sedimentary rocks, and silty limestone units that are intercalated with the chert in the lower part of the sequence. Although the latter lithologies can be seen in places to be clearly interbedded with argillite and chert, these sequences could well be tectonically interleaved with the thin-bedded purer chert packages that contain the abundant radiolaria.

The data discussed above strongly suggest that the base of the Schoonover sequence is not an unconformity but is everywhere a major thrust fault. This contact places Schoonover greenstone units and structurally overlying Early Mississippian radiolarian chert and argillite over Upper Mississippian to Permian shallow-water rocks deposited unconformably on deformed lower Paleozoic strata. This thrust fault places older over younger rocks and juxtaposes sequences deposited in highly dissimilar paleogeographic terranes. The Schoonover sequence is more highly deformed than the underlying strata beneath the thrust fault, and structural data from the Schoonover (Fig. 2) are compatible with a NW-SE direction of maximum shortening. In conclusion, major NW-SE directed telescoping of geographically distant, partially time-equivalent rock assemblages has occurred along the thrust fault at the base of the Schoonover sequence.

TIMING OF EVENTS AND DISCUSSION

Ordovician Valmy-equivalent rocks in the northern Independence Mountains are strongly deformed and are overlain unconformably by

Upper Mississippian shallow water rocks along Schoonover Creek. We concur with the interpretation of Churkin and Kay (1967) that this unconformity in the northern Independence Mountains is a consequence of deformation that occurred during the latest Devonian to earliest Mississippian Antler Orogeny, but we conclude that the rocks directly above the unconformity are probably correlative to the overlap assemblage of Roberts and others (1958), and are not the basal units of the Schoonover sequence, whose base is everywhere a thrust fault in the Independence Mountains. Similar overlap assemblage sequences, deposited unconformably above lower Paleozoic eugeoclinal rocks, have been described to the north of the Independence Mountains by Coats (1971) and Coats and Gordon, (1972). Thus, the lower Paleozoic rocks deformed during the Antler orogeny and the units that unconformably overlie these are autochthonous with respect to the allochthonous Schoonover sequence. The Schoonover allochthon was emplaced after the deposition of the youngest rocks present beneath the thrust fault. In one locality, these rocks contain detrital brachiopods dated as Late Permian. Unfortunately, the only rocks that provide an upper age bracket for thrusting in the map area are Miocene volcanic rocks that unconformably overlie the Schoonover sequence (Decker, 1962) (Fig. 2). This leaves open the possibility, but does not demonstrate, that the episode of thrusting that emplaced the Schoonover may have been time-equivalent to the Permo-Triassic age thrust that emplaced the Golconda allochthon in north central Nevada.

The Lower Mississippian to Lower Pennsylvanian range of ages from the Schoonover sequence partially overlaps the Late Mississippian to Permian age span of the Havallah Sequence, however, the Lower

Mississippian (and possibly uppermost Devonian) ages for radiolarian chert near the structural base of the Schoonover represent the oldest dates obtained thus far from the Upper Paleozoic deep-water rock assemblages of Nevada. The Havallah sequence in north central Nevada is not yet adequately dated and may eventually also yield older ages. The Schoonover sequence and the Havallah sequence are strikingly similar both lithologically and structurally (W. Snyder, pers. comm. 1979), thus their equivalence seems likely, and certainly at least parts of both were deposited in the same paleogeographic setting.

It is interesting to note that although most workers generally agree that the Golconda allochthon was probably emplaced in Permo-Triassic times, the original paleogeographic position of this deep-water sequence is not well known. The sedimentologic ties between these rocks and coeval strata deposited along the North American shelf, as well as the relationship of these sequences to the arc(s)(?) and subduction zone(s)(?) postulated to have ultimately caused their deformation and emplacement still remain highly debated and somewhat of an enigma in Cordilleran geology (see for instance Burchfiel and Davis, 1975; Dickinson, 1977; Speed, 1979).

The Lower Mississippian to Lower Pennsylvanian pelagic cherts in the lower part of the Schoonover sequence are partly contemporaneous with the Upper Mississippian non-marine to shallow marine overlap assemblage rocks present along Schoonover Creek. Furthermore, chert-argillite units near the base of the allochthonous Schoonover sequence were deposited in a pelagic environment, and other units in this part of the sequence received detritus from explosive volcanic centers. These rocks are dated as Lower Mississippian and are possibly as old as uppermost Devonian in one locality. Thus, the age of the lower portion of the Schoonover sequence may overlap the age of the Latest Devonian-Early Mississippian Antler Orogeny. This orogenic event, at least in Nevada, was not accompanied by volcanism. These disparities in provenance characteristics, depositional environments, and geologic history between "overlap assemblage" rocks and the Schoonover sequence argues that the Schoonover sequence (and the Havallah sequence if the two are equivalent) was at least in part deposited in a location paleogeographically distant from the edge of the North American shelf.

Perhaps the next question to ask is exactly <u>how</u> far apart these two assemblages once were. Additional work on the petrography and provenance of detrital sequences in the Schoonover is required to resolve this question.

The composition of most of the detrital units within the Schoonover is compatible with derivation from the erosion of Roberts Mountains allochthon rocks. Was this debris derived from the erosion of rocks emplaced onto the North American shelf during the Antler Orogeny, or from similarly deformed rocks much further offshore? Are these particular detrital sequences interbedded with or tectonically interleaved with sequences derived from a volcanic source? If dual sources (volcanic and Roberts Mountains allochthon) are represented in the same stratigraphic packages, then arguments in favor of deposition of the Schoonover-Havallah sequences in a ~~marginal~~ back arc basin setting might be preferred. An additional complication we are faced with at this time is that we do not fully understand the structural, stratigraphic, and age relationship between these various detrital sequences and the intercalated purer radiolaria chert units that we have dated.

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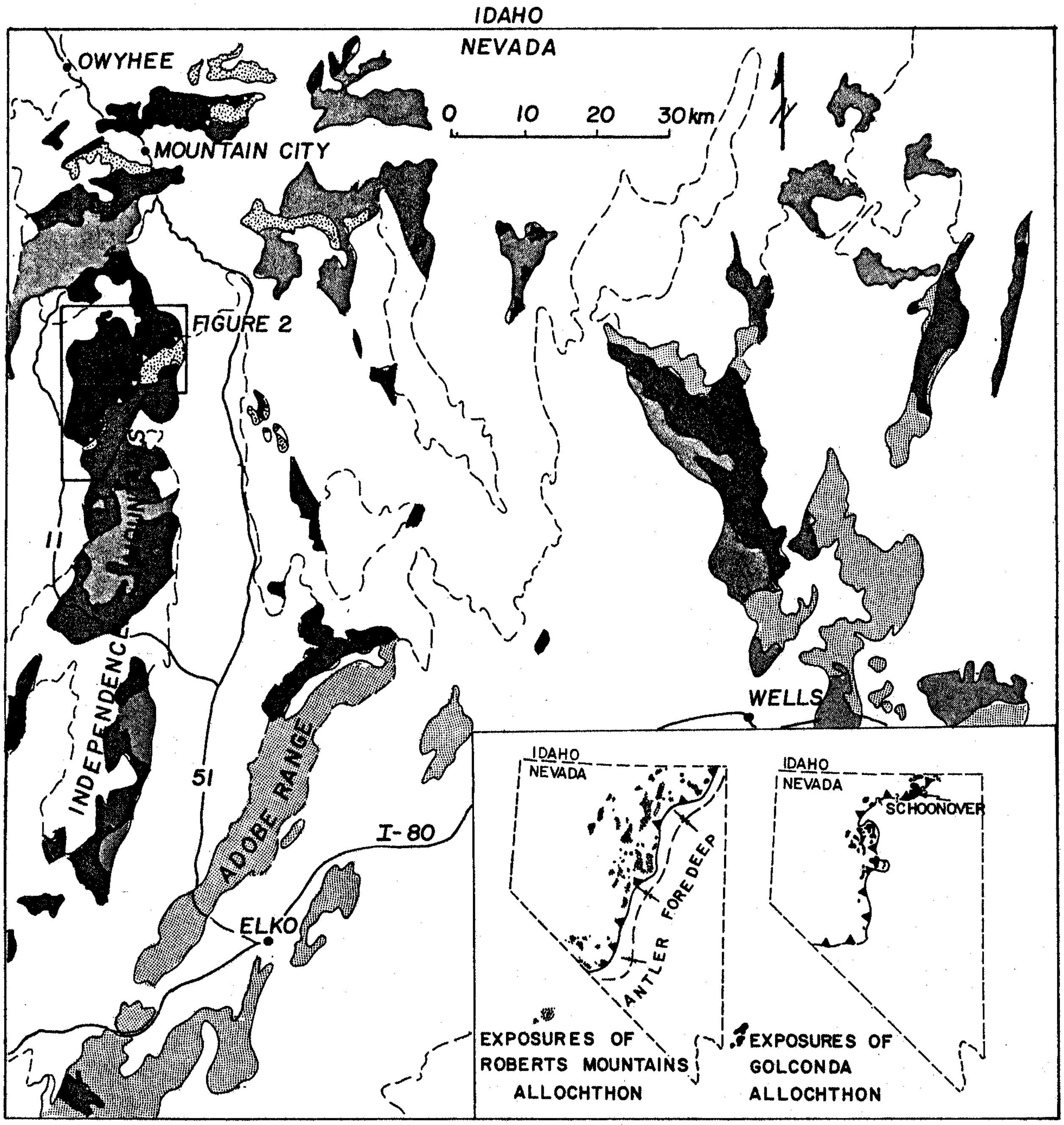
Figure Captions

Figure 1. Simplified geologic map of northeastern Nevada showing the general distribution of rock types discussed in text in relationship to the Independence Mountains map area, modified from Stewart and Carlson (1978). Dashed lines are outlines of ranges. Inset maps showing present trace of Roberts Mountains thrust and Golconda thrust modified from Stewart and others (1977), Stanley and others (1977), Poole and Sandberg (1977) and Speed (1979).

Figure 2. Simplified geologic map and structural data of the northern Independence Mountains, modified from Churkin and Kay (1967), Fagan (1962), Decker (1962); modifications by the Stanford Geological Survey (1979). Fossil localities are described in detail in Table I.

Figure 3. Photomicrographs: A, Graded tuff bed with euhedral plagioclase grains, interbedded with tuffaceous chert from locality of radiolarian sample 2-6.. B, Volcanogenic turbidite unit containing volcanic quartz and plagioclase, also from the basal portion of the Schoonover sequence.



Upper Paleozoic allochthonous deep water rocks

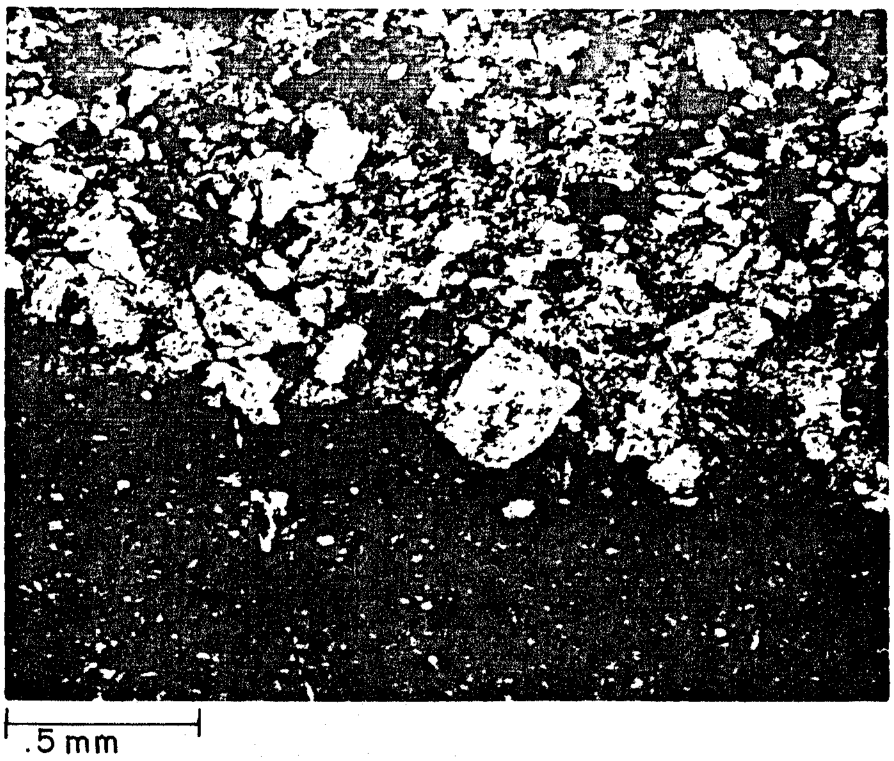
Carbonate and detrital sequences deposited unconformably on Lower Paleozoic allochthonous rocks of Antler orogenic belt

Detrital rocks deposited in Antler foredeep basin

Lower Paleozoic allochthonous rocks of Antler orogenic belt

Miogeoclinal and transitional assemblage rocks

GEOLOGIC MAP MODIFIED FROM STEWART AND CARLSON (1978)



A.

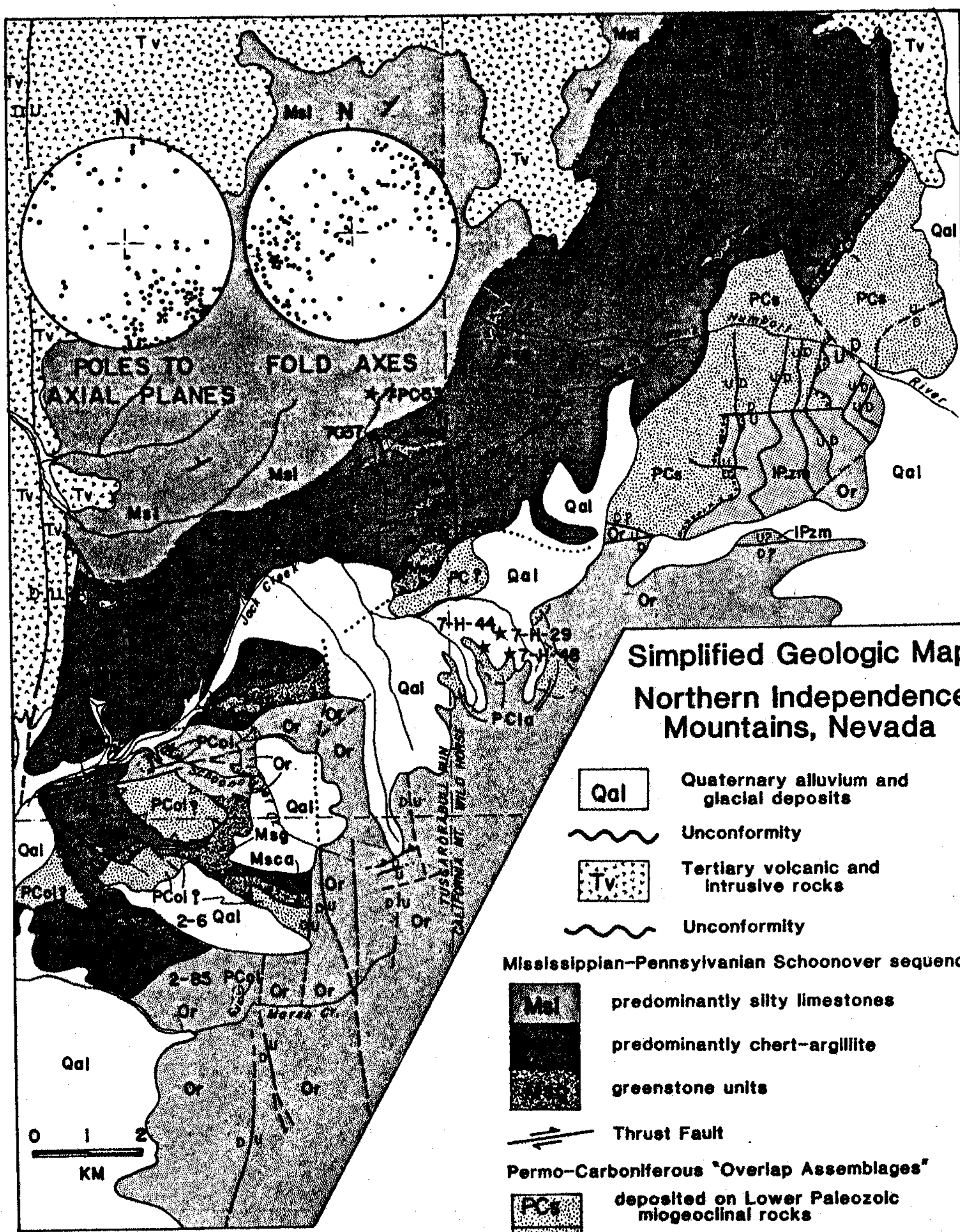
B.

Figure 3

TABLE I

Sample #	Latitude	Longitude	Age	Fossils, Lithology, Formations, Map units
Bull Run 15'Quadrangle				
7-PC-53	N41 34'.20°	W116 00'.94°	Early Pennsylvanian	Radiolarian chert, Ott Creek Member, Schoonover Formation (Fagan, 1962)
7-C-37	N41 33'.78°	W116 00'.86°	Middle Mississippian	Radiolarian chert, Harrington Creek Member, Schoonover Formation (Fagan, 1962)
7-H-2	N41 32'.73°	W116 00'.70°	Middle Mississippian	Radiolarian chert, Dorsey Creek Member, Schoonover Formation (Fagan, 1962)
5-17	N41 32'.54°	W116 03'.09°	Early Mississippian	Radiolarian chert, Cap Winn Member/Harrington Creek Member, Schoonover Formation (Fagan, 1962)
4-B-11	N41 32'.09°	W116 03'.67°	Mississippian (probably Upper)	Radiolarian chert, Harrington Creek/Mike's Creek Member, Schoonover Formation (Fagan, 1962)
3-M-74	N41 32'.17°	W116 04'.40°	Late Mississippian	Radiolarian chert, Cap Winn Member, Schoonover Formation (Fagan, 1962)
5-7	N41 31'.62°	W116 03'.12°	Probably Mississippian	Radiolarian chert, Fry Creek/Mike's Creek Member, Schoonover Formation (Fagan, 1962)
5-5	N41 31'.44°	W116 03'.15°	Late Mississippian	Radiolarian chert, Fry Creek/Mike's Creek Member, Schoonover Formation (Fagan, 1962)
5-41	N41 31'.21°	W116 03'.02°	Late Mississippian	Radiolarian chert Mikes Creek/Dorsey Creek Member, Schoonover Formation (Fagan, 1962)
Pcol	N41 30'.68°	W116 03'.77°	Upper Mississippian (Chester) R. Coats (1980)	brachiopods, conodonts; Overlap Assemblage of Stanford Geol. Survey, unpublished mapping; PCsc of Churkin and Kay (1962)
Tuscarora 15' Quadrangle				
2-6	N41 28'.97°	W116 03'.77°	Earliest Mississippian (-Upper Devonian?)	Radiolarian chert, undifferentiated Schoonover Formation (Churkin and Kay, 1962)
Wild Horse 15'Quadrangle				
7-11-29	N41 31'.72	W115 59'.32	Late Permian (T. Dutro, written communication, 1979)	reworked brachiopods Timaniella, Spirifella, Yakolevia, lithic arenite, PCsg of Churkin and Kay (1967)

/V ?



Simplified Geologic Map Northern Independence Mountains, Nevada

Qal — Quaternary alluvium and glacial deposits

Unconformity

Tv — Tertiary volcanic and intrusive rocks

Unconformity

Mississippian–Pennsylvanian Schoonover sequence

- Msl — predominantly silty limestones
- predominantly chert–argillite
- greenstone units

Thrust Fault

Permo–Carboniferous "Overlap Assemblages"

- PCs — deposited on Lower Paleozoic miogeoclinal rocks
- PCla — lithic arenite
- PCol — deposited on Ordovician eugeoclinal rocks
- basal conglomerate

Unconformity

Ordovician Roberts Mountains Allochthon

- Or — argillite, quartzite and chert

High Angle Fault

Cambrian and younger(?)

- lPzm — Lower Paleozoic miogeoclinal rocks

Symbols

- Contacts: dashed where approximate or inferred, dotted where concealed.
- Faults: dashed where approximate or inferred, dotted where concealed
- thrust fault
- fault with vertical displacement
- strike and dip of layering
- ★ fossil locality

MODIFIED FROM CHURKIN AND KAY (1967) FAGAN (1962), DECKER (1962)

GEOLOGIC MAP OF NORTHERN INDEPENDENCE MTS ELKO CO., NEVADA

EXPLANATION

QUATERNARY

Qts
Colluvium

Qal
Alluvial and fluvial deposits of present-day rivers and streams

Qoal
Alluvial and fluvial deposits incised by present-day rivers and streams, possibly related to Qgo

Qgo
Glacial outwash-debris deposited from periglacial streams

Qag
Glacial moraine-debris deposited directly from glaciers

TERT.

Tv
Undifferentiated welded to unwelded rhyolitic to dacitic ash flow tuffs with minor airfall tuffs interbedded. KSP-PLAG-QZ-BIO±HB phenocrysts in devitrified groundmass; Locally differentiated into Tv_1-rhyolitic ash flow tuff directly above Schoonover sequence and overlain by Tv_2, HB-bearing ash flow in turn overlain by undifferentiated Tv

PENNSYLVANIAN –?– MISSISSIPPIAN

SCHOONOVER SEQUENCE

CssL
Predominantly turbiditic silty clastic limestone and calcareous sandstone interbedded with chert shale, and non-calcareous sandstones

Css
Turbiditic sandstone (····), pebble conglomerate (ooooo), and siltstone, interbedded with shale and chert (–·–·–), Locally feldspathic (F···F···) and tuffaceous (···v···v··).

Csd
Diamictite (···D···D···) with sand to boulder-sized chert, quartzite, and rare greenstone and limestone clasts enclosed in a mudstone matrix. Interbedded with shale, sandstone and conglomerate

Csca
Chert (–·–·–) and shale, in varying ratios, with rare interbedded sandstone and local manganese mineralization (–Mn–)

Csi
Concordant diabasic intrusions confined to greenstone pile

Csg
Basaltic(?) greenstone: Massive and pillowed flows, pillow breccias, and laminated tuffs

SCHOONOVER THRUST

PERMIAN

OVERLAP ASSEMBLAGE

PoL
Predominantly calcareous siltstone and silty limestone with interbedded calcareous sandstone and chert and quartz-rich coarser sandstone. Lithic arenite interbedded with argillite and occasional radiolarian chert present locally. Deposited on both lPzm and Ov

PoL2
Calcareous sandstone and grit; reefal bioclastic limestone locally present. Deposited on lPzm only

PoL1
Basal limestone-chert-quartzite pebble to cobble conglomerate. Deposited on lPzm only

UNCONFORMITY

ORDOVICIAN

ROBERTS MOUNTAIN ALLOCHTHON

Valmy quartzite

(includes McAfee Quartzite, Jack's Peak chert, and Jack's Peak Quartzite as defined and mapped by Churkin and Kay, 1967).

Ovq
Predominantly massive cliff-forming quartzite (·····) interbedded with siliceous shales, black graptolitic shales, and minor chert (–·–·–)

Ovca
Chert (–·–·–) and shale

Snow Canyon Formation (Churkin and Kay, 1967)

Osu
Interbedded quartzite, sandstone, shale, chert and rare limestone. Becomes more quartzite-rich upsection; transitional with overlying Valmy quartzite.

Osc
Chert and minor shale

OsL
Massive to thin-bedded, locally chertified limestone occurring as discontinuous blocks in Osu.

Osg
Basaltic (?) greenstone: Predominantly massive, rarely pillowed, flows and flow breccias. Slightly vesicular, somewhat porphyritic. Some calcareous material interstitial to breccia fragments. Predominant Snow Canyon lithology.

ROBERT'S MOUNTAIN THRUST (not exposed in the map area)

–?–

CAM.

MIOGEOCLINAL SEQUENCE

lPzm
Thin-bedded limestone and limestone, cherty limestone, locally chertified limestone, and dolomite. Penetratively deformed with well-defined axial plane cleavage.

SYMBOLS

- Contact, dashed where approximately located, queried where existence uncertain, dotted where concealed
- 96 Strike and dip of bedding, facing unknown
- 47 Strike and dip of upright beds
- 85 Strike and dip of overturned beds
- Strike of vertical beds
- Fault, dashed where approximately located, queried where existence uncertain, dotted where concealed
- Thrust fault, teeth on upper plate
- U/D Fault showing relative vertical movement
- Fault showing relative horizontal movement
- 23 Synform
- 6 Antiform
- 14 Trend, plunge, and sense of rotation of fold axis
- 78 Strike and dip of axial plane
- Strike of vertical axial plane
- Silicified

- ◇ Megafossil sample
- ★ Radiolaria sample
- ◆ Conodont sample
- ■ Paleomag sample

TN MN 17½°

Base maps: U.S. Geological Survey topographic quadrangle maps:
Bull Run 15′, Wild Horse 15′, Tuscarora 15′, California Mountain 7.5′.

Geologic mapping by Stanford Geologic Survey, June 16 - July 29, 1980:

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0 ½ 1 2 3 4 MI

0 ½ 1 2 3 4 KM

Contour interval 40 feet

This map has been edited and reviewed for conformity with Stanford Geological Survey standards...but no one else's.