PREFACE

The following information is a supplement to the paper: *Mesozoic tectonics and metamorphism in the Pequop Mountains and Wood Hills region, northeast Nevada: implications for the architecture and evolution of the Sevier orogen,* by P.A. Camilleri and K.R. Chamberlain. The purpose of this supplement is to provide more detailed information on the metamorphic rocks in the Pequop Mountains, Wood Hills, and Windermere Hills, and in particular, to document how we established the distribution of metamorphic facies in these ranges (Fig. 1). We proceed with the assumption that the reader is familiar with the paper. In this supplement we present some new figures in addition to those already published. We have numbered all of the figures in the supplement consecutively. Consequently, this means that figures that appear in both the supplement and the paper are numbered differently.

INTRODUCTION

The metamorphosed section in the Wood Hills, Windermere Hills, and Pequop Mountains consists predominantly of meta-carbonate rocks with minor meta-siliciclastic strata (Fig. 2). Metapelites in this region yield assemblages indicative of Barrovian metamorphism and allowed mapping of greenschist, lower amphibolite, and upper amphibolite facies metamorphic zones (Fig. 1). We utilized assemblages in meta-siliceous dolomites to map calc-silicate isograds and metamorphic zones (Fig. 1), and we correlated the calc-silicate metamorphic zones with metapelitic zones in order to delineate metamorphic grade in areas where diagnostic metapelites are not exposed. Figure 3 shows the correlation of major metamorphic minerals in different types of protoliths with metamorphic grade.

In the next sections we discuss metamorphic assemblages in metapelites and meta-siliceous dolomites. Metapelites are discussed first to establish metamorphic grade and then meta-siliceous dolomites are discussed to establish calc-silicate metamorphic zones, which are then used to infer metamorphic grade where diagnostic metapelites are not exposed. Mineral abbreviations used in the text are listed in Table 1.

METAPELITES

The metamorphosed section has four main units that contain metapelites useful for assessment of metamorphic grade: the Mississippian Chainman Shale-Diamond Peak Formation, Kanosh Shale of the Ordovician Pogonip Group, Upper Cambrian Dunderberg Shale, and Lower Cambrian Prospect Mountain Quartzite (Fig. 2). Figures 4 and 5 are maps of the Pequop Mountains and Wood Hills that show the locations of assemblages in metapelitic samples of these units. Because metapelites are stratigraphically punctuated by thick sections of carbonate (Fig. 1), first-appearance mineral isograds and facies boundaries (as shown in Figs. 1 and 4) for metapelites are approximately located.

Pequop Mountains

The Paleozoic section beneath the Pequop fault in the Pequop Mountains ranges from unmetamorphosed to lower amphibolite facies (Fig. 1) and assemblages in metapelites indicate that metamorphic grade increases with stratigraphic depth. The transition between metamorphosed and non-metamorphosed rocks lies between the Chainman Shale-Diamond Peak Formation and the Kanosh Shale, a zone which is composed predominantly of limestone and dolostone (Fig. 6). The Chainman Shale-Diamond Peak Formation is unmetamorphosed whereas the Kanosh Shale is an argillite or a Q-SER-CHL phyllite (Fig. 6) and therefore lies within the chlorite zone. The biotite-in isograd lies between the Kanosh and Dunderberg Shales in the footwall of the Independence thrust (Figs. 4 and 5), however, in the hanging wall of the thrust, the biotite-in isograd transects the Dunderberg Shale (Fig. 4). The chlorite zone assemblage in the Dunderberg Shale is SER-CHL-Q (Fig. 4) and in the biotite zone is BI-MU-CHL-TOUR-ALL-PL-Q $\pm$ CC/EP (Fig. 4). The garnet-in isograd lies between the Dunderberg Shale and the Prospect Mountain Quartzite (Figs. 4 and 6). Micaceous layers within the Prospect Mountain Quartzite contain the prograde assemblage Q-MU-BI-GT-PL (Fig. 4).

Overall, the distribution of metamorphic assemblages in the Pequop Mountains clearly indicate that metamorphic grade increases with stratigraphic depth (Fig. 6). However, slight nonparallelism of isograd surfaces to stratigraphic contacts is indicated by the transection of the Dunderberg Shale by the biotite-in isograd in the hanging wall of the Independence thrust (Fig. 4).

Wood and Windermere Hills

In contrast to the Pequop Mountains, the Wood Hills are of much higher metamorphic grade as indicated by the presence of kyanite and absence of prograde chlorite in metapelites. Two main metapelitic units are exposed in the Wood Hills; the Dunderberg Shale and the Kanosh Shale.

The Dunderberg Shale is the stratigraphically lowest exposed metapelitic unit in the Wood Hills. Typical assemblages in the Dunderberg Shale [schist], in order of decreasing abundance, are: BI-MU-Q-PL-ALL-TOUR $\pm$ CC; BI-MU-KY-ST-Q-PL-ALL; BI-ST-KY-GT-MU-Q-PL-ALL-RT-IL. The kyanite-bearing schists were found in only two localities (Fig. 5). In the easternmost locality (Fig. 5) Thorman (1970) reported andalusite [with kyanite] in the Dunderberg Shale. However, after studying several (>10) thin sections of the kyanite-bearing schists from this locality and not observing any andalusite, we conclude that andalusite does not exist in the Dunderberg Shale in the Wood Hills. The presence of kyanite in the Dunderberg Shale indicates that these rocks are in the kyanite zone or upper amphibolite facies.

The Kanosh Shale is the stratigraphically highest exposed metapelitic unit in the Wood Hills and it does not vary significantly with respect to mineral constitution (Fig. 5). It contains a typical assemblage of BI-MU-Q-KFS-TOUR-All (Fig. 5). The association of this assemblage with the kyanite-bearing schists of the Dunderberg Shale indicates that the Kanosh assemblage is stable in the kyanite zone. The Kanosh Shale is not a true pelite in the sense that within the amphibolite facies it does not yield high-aluminum metamorphic minerals. Despite the lack of variance in mineral assemblage, the Kanosh Shale exhibits textural changes with respect to fabric. The Kanosh Shale is a phyllite in the southeastern corner of the Wood Hills and is a schist to the northwest (Fig. 5).

The only metapelite exposed in the Windermere Hills, which is a northern extension of the Wood Hills metamorphic terrain (Mueller, 1992; Fig. 1), is the Chainman Shale-Diamond Peak Formation. There, the Chainman Shale comprises very fine-grained, Q-SER-CHL-BI phyllite. Depending on bulk rock composition, the Chainman Shale could be in either greenschist or lower amphibolite facies. Although these rocks are shown as lower amphibolite facies on Figure 1, it is equally possible that they are greenschist facies: the data are undiagnostic. The presence of prograde chlorite in the Windermere Hills contrasts with the Wood Hills, where metapelites do not contain prograde chlorite. This clearly indicates a higher metamorphic grade for rocks in the Wood Hills, which are also stratigraphically lower and hence were structurally deeper than rocks in the Windermere Hills during metamorphism.

META-SILICEOUS DOLOMITE

Calc-silicate assemblages in meta-siliceous dolomite were used to define tremolite- and diopside-in isograds (Figs. 4 and 7) and to infer metamorphic grade in areas where metapelites are not exposed in the Wood Hills and Pequop Mountains. Siliceous dolomite occurs at the base of the Devonian Simonson Dolomite, in the Silurian Roberts Mountains Formation and Fish Haven Dolomite, in the Orodovician Pogonip Group, and in various Cambrian units (Fig. 1). Because siliceous dolomite is stratigraphically punctuated by other rock compositions and the sampling density of calc-silicate-bearing rocks is only moderate, calc-silicate isograds are approximately located. More detailed sampling would produce more precise placement of isograds but probably would not significantly alter their inferred regional trends.

Pequop Mountains

In the Pequop Mountains, the first appearance of tremolite occurs < 200 m above the first appearance of garnet in metapelite and is in proximity of the first appearance of hornblende in meta-argillaceous limestone (Fig. 6). This suggests that the tremolite-in isograd is within lower amphibolite facies. Because of the proximity of the first appearance of tremolite in metacarbonate and garnet in metapelite, we interpret the tremolite-in isograd to coincide approximately with the garnet-in isograd. Hence we interpret the presence of tremolite within the Pequop Mountains to indicate lower amphibolite facies. Using this inference, we assigned rocks beneath the tremolite-in isograd in the hanging wall of the Independence thrust, which lack metapelite, to lower amphibolite facies (Fig. 1).

Wood Hills

The Wood Hills are divided into talc, tremolite, and diopside zones separated by northeast-trending tremolite- and diopside-in isograds (Fig. 7). Figure 7 shows the locations and assemblages of samples used to define positions of the isograds.

Some of the calc-silicate assemblages in the Wood Hills can be used to establish spatial thermal variations across isograds. Figure 8 is a plot of reaction relationships in the system CaO-MgO-SiO_2-CO_2-H_2O in T-XCO_2 space. The plot assumes end member mineral compositions and a pressure of 6 kb, which is derived from Hodges et al. (1992) estimate of metamorphic pressure of 5.5 to 6.4 kb for the Dunderberg Shale in the southern Wood Hills. Samples numbered 5, 6, and 7 in the talc zone (Fig. 7) contain the assemblage CC-DO-Q-TLC, which is stable along reaction [1] and requires temperatures < ~ 470 °C (Fig. 8).

The tremolite zone encompasses exposures of kyanite-bearing schists of the Dunderberg Shale from which Hodges et al. (1992) derived a metamorphic temperature of ~ 540 to 590 °C (zone "a" in Fig. 8). Tremolite bearing assemblages within the tremolite zone (Fig. 7) are stable within a region in T-XCO_2 space delimited by reactions [2], [4], and [7] (zone "b" in Fig. 8). In addition, in proximity of the kyanite-bearing schist, sample 10B (Fig. 7) has an assemblage of TR-CC-Q which has a more restricted zone of stability bounded by reactions [2], [4], and [5], and requires a temperature of < ~ 620 °C. This is compatible with Hodges et al. (1992) temperature estimate of ~ 540 to 590 °C.

Diopside zone assemblages, exclusive of those overprinted in the mylonite zone (Fig. 7), lie on or above curves representing reactions [5] and [6] (Fig. 8). In proximity of the diopside-in isograd, the assemblage DI-TR-CC-Q (location # 18; Fig. 7) in the southern Wood Hills lies along reaction [5], which requires a temperature < ~ 620 °C. Away from the tremolite-in isograd, in the northwestern Wood Hills, the assemblage DI-DO-Q (in samples 19 and 21; Fig. 7) lie on curve [6] which suggests a temperature between ~ 620-640 °C. Comparison of equilibrium calc-silicate assemblages in the Wood Hills with the isobaric T-XCO_2 plot suggest a northwest increase in temperature.

The mylonite zone in the northwestern part of the Wood Hills overprints much of the rocks in the diopside zone. Diopside within mylonitic rocks is not a stable phase. In mylonitic rocks, diopside typically forms porphyroclasts with asymmetric tails of TR-CC-Q wherein the tails record the retrograde reaction DI + H_2O + CO_2--> TR + CC + Q. Assemblages stable within the mylonite zone can't be compared to the isobaric T-XCO_2 plot in Figure 8 because the mylonites facilitated decompression and it is unknown at what pressure in the decompression history the samples underwent retrogression.

The presence of kyanite within the tremolite zone indicates that the tremolite zone, and by inference the diopside zone, are within upper amphibolite facies. The presence of diopside therefore serves to divide the upper amphibolite facies into probable lower and higher temperature end-members. Precise correlation of the talc zone with metapelitic metamorphic zones is not possible because no metapelites with diagnostic assemblages crop out within this zone. However, the presence of chlorite-absent biotite schist or phyllite and an estimate of metamorphic temperatures of < ~ 470 °C (based on calc-silicate equilibria) in the talc zone suggests lower amphibolite facies conditions. Therefore, we assigned rocks in the talc zone to lower amphibolite facies (Fig. 1).

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FIGURE CAPTIONS--CAMILLERI AND CHAMBERLAIN DATA REPSITORY

Figure 1. Metamorphic map of the Pequop Mountains, Wood Hills, Spruce Mountain, and Ruby Mountains-East Humboldt Range. Data from the Wood Hills-Windermere Hills and northern Pequop Mountains is simplified from Camilleri (1994). Data from the southern Pequop Mountains is integrated from Coats (1987); Spruce Mountain from Hope (1972), Coats (1987), and our observations; the Ruby Mountains and East Humboldt Range from Snoke and Lush (1984), Howard et al. (1979), Taylor (1981), Hudec, (1992), McGrew (1992); Snake Mountains from Coats (1987). The position of the sillimanite-in isograd is constrained by data from Howard (1966), Taylor (1981), Hurlow et al. (1991), McGrew (1992), Snoke (1992), and Hodges et al. (1992). Barometric data shown in the Wood Hills is from Hodges et al. (1992); in the East Humboldt Range from McGrew (1992) and Peters and McGrew (1994); and the Ruby Mountains from Hudec (1992).

Figure 2. Generalized stratigraphic column of Proterozoic to Mesozoic strata in northeast Nevada. The column depicts average stratigraphic thicknesses and depths prior to Mesozoic deformation and metamorphism. Data used in constructing this column are from Camilleri 1994; McCollum and Miller, 1991; Miller, 1984; Glick, 1987; Thorman, 1970; Robinson, 1961; and Fraser et al. 1986.

Figure 3. Chart of major metamorphic minerals versus protolith and metamorphic grade for the Pequop Mountains and Wood Hills. Stippled region denotes metamorphic zones for which a particular pelitic unit is not exposed.

Figure 4. Metamorphic map of the Pequop Mountains showing locations of assembles in metapelitic and meta-siliceous dolomite samples. X-X' is the location of the cross section depicted in Figure 6. Dashed lines are isograds. Data from Camilleri (1994)

Figure 5. Metamorphic map showing the locations of assemblages in metapelite samples in the Wood Hills. Gray dashed lines are the diopside- and tremolite-in isograds.

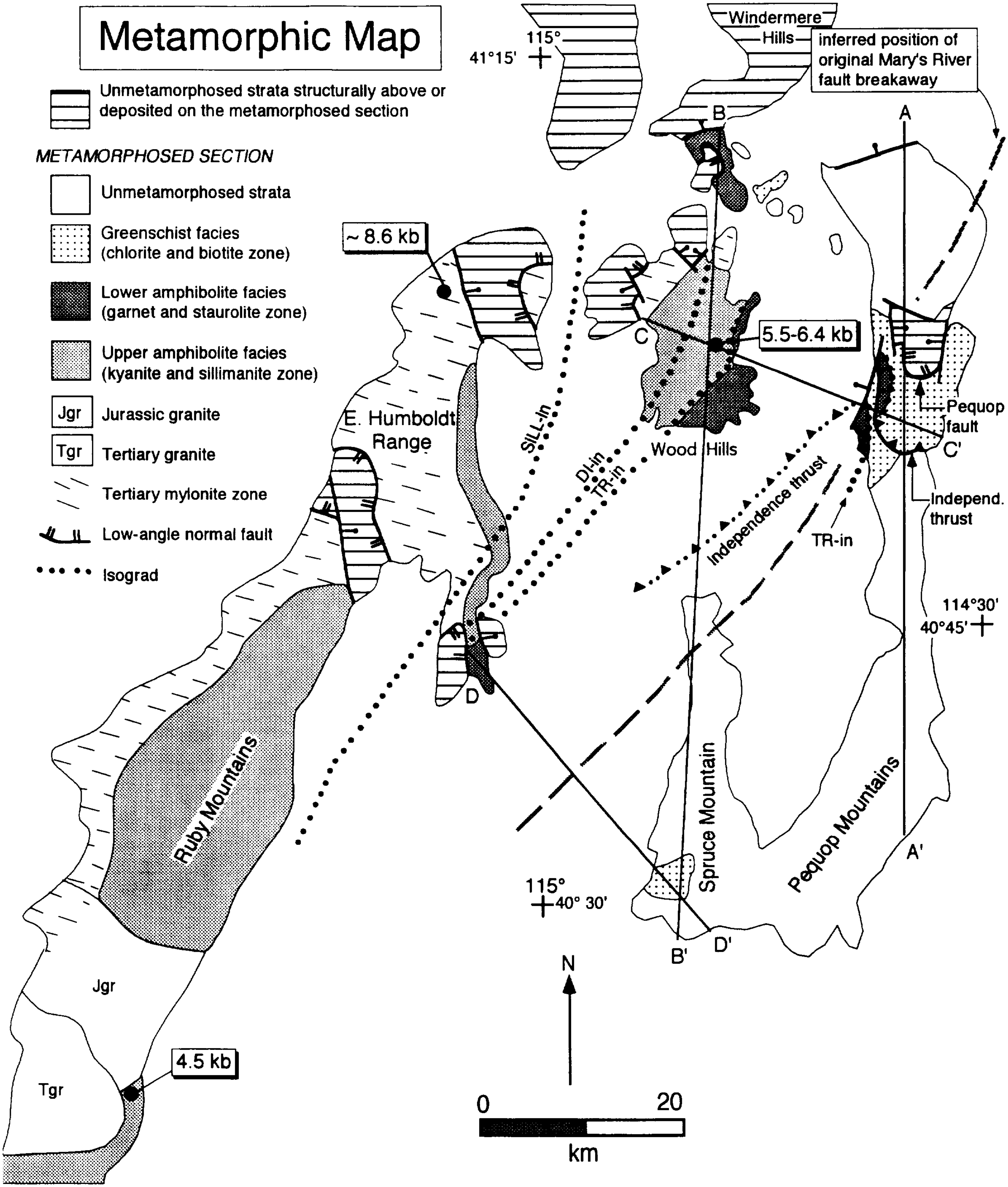
Figure 6. Detailed cross section through the footwall of the Independence thrust in the Pequop Mountains illustrating metamorphic mineral assemblages in various units. Location of section is shown in Figure 4. ZCpm = Prospect Mountain Quartzite; Cks = Killian Springs Formation; Ct = Toano Limestone; Ccl = Clifside Limestone; Cu = upper Cambrian limestone, undivided; Cd = Dunderberg Shale; Cnp = Notch Peak Formation; Op = Pogonip Group; Oe = Eureka Quartzite; OMu = Ordovician, Silurian, Devonian and lower Mississippian strata, undivided; Mdpc = Diamond Peak Formation and Chainman Shale, undivided; Pe = Ely Limestone.

Figure 7. Metamorphic map of the Wood Hills showing locations of assemblages in calc-silicate samples and the approximate locations of the tremolite-in and diopside-in isograds.

Figure 8. T-XCO2 plot for the system CaO, MgO, SiO, H_20, CO_2 at 6 kb. Grid generated by GEO-CALC (Perkins et al., 1986) using the data base of Berman et al. (1985). Plot assumes end-member compositions. See text for explanation.

TABLE 1. MINERAL ABBREVIATIONS

AND	andalusite	GT	garnet	SILL	sillimanite
ALL	allanite	HNB	hornblende	SP	sphene
ALS	aluminosilicate	IL	ilmenite	ST	staurolite
BI	biotite	KFS	potassium feldspar	TLC	talc
CC	calcite	MIC	microcline	TOUR	tourmaline
CHL	chlorite	MU	muscovite	TR	tremolite
DI	diopside	PL	plagioclase	KY	kyanite
DO	dolomite	RT	rutile	Q	quartz
EP	epidote	SER	sericite		



Metamorphic Map
Unmetamorphosed strata structurally above or deposited on the metamorphosed section
METAMORPHOSED SECTION
Unmetamorphosed strata
Greenschist facies (chlorite and biotite zone)
Lower amphibolite facies (garnet and staurolite zone)
Upper amphibolite facies (kyanite and sillimanite zone)
Jgr Jurassic granite
Tgr Tertiary granite
Tertiary mylonite zone
Low-angle normal fault
Isograd
115°
41°15'
Windermere Hills
inferred position of original Mary's River fault breakaway
A
B
~ 8.6 kb
5.5-6.4 kb
C
C'
Pequop fault
Independ. thrust
E. Humboldt Range
SILL-in
DI-in
TR-in
Wood Hills
Independence thrust
TR-in
114°30'
40°45'
D
Ruby Mountains
Spruce Mountain
Pequop Mountains
A'
115°
40° 30'
B'
D'
N
0
20
km
Jgr
Tgr
4.5 kb

Figure 1.

Proterozoic-Mesozoic stratigraphy

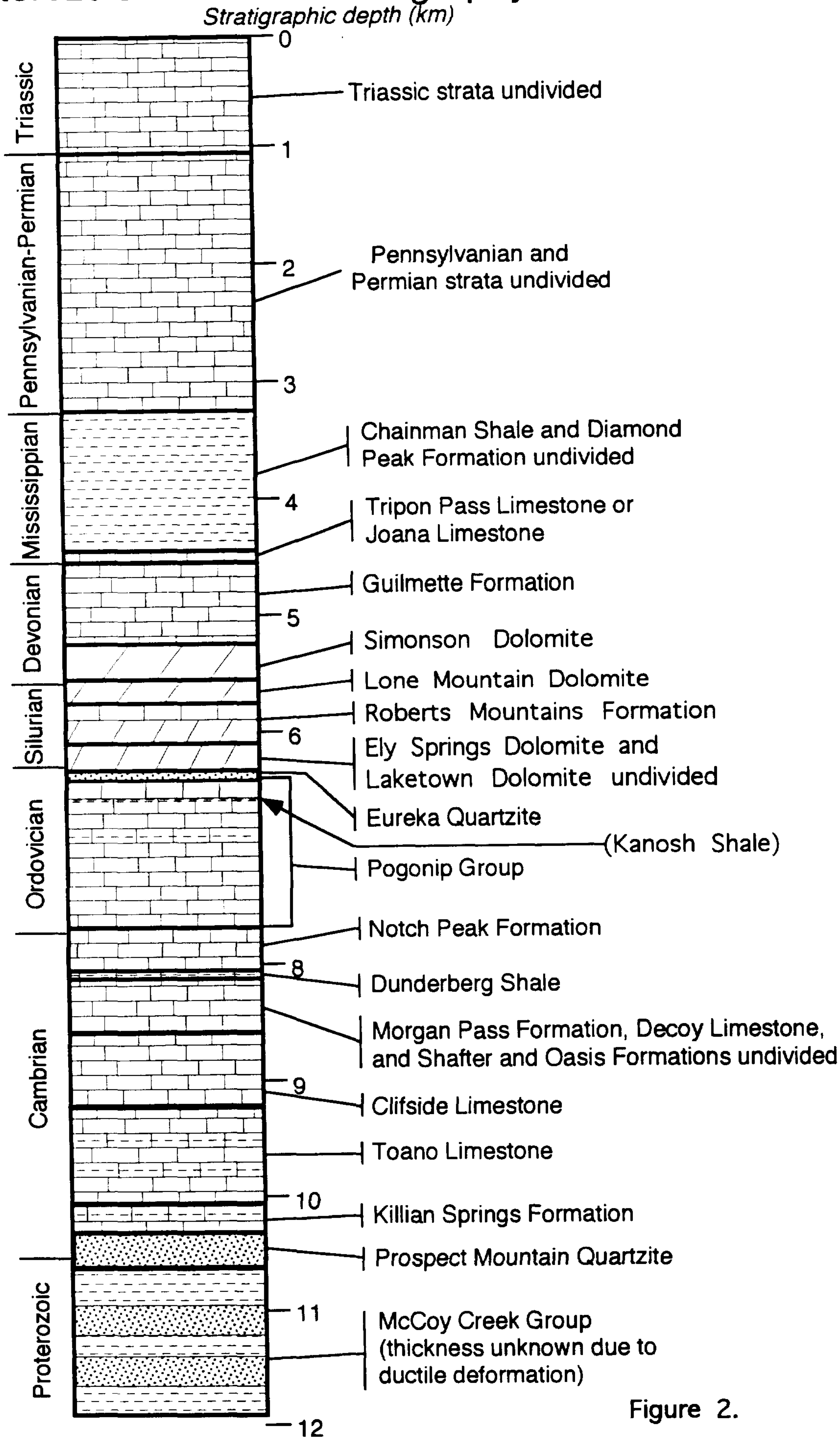
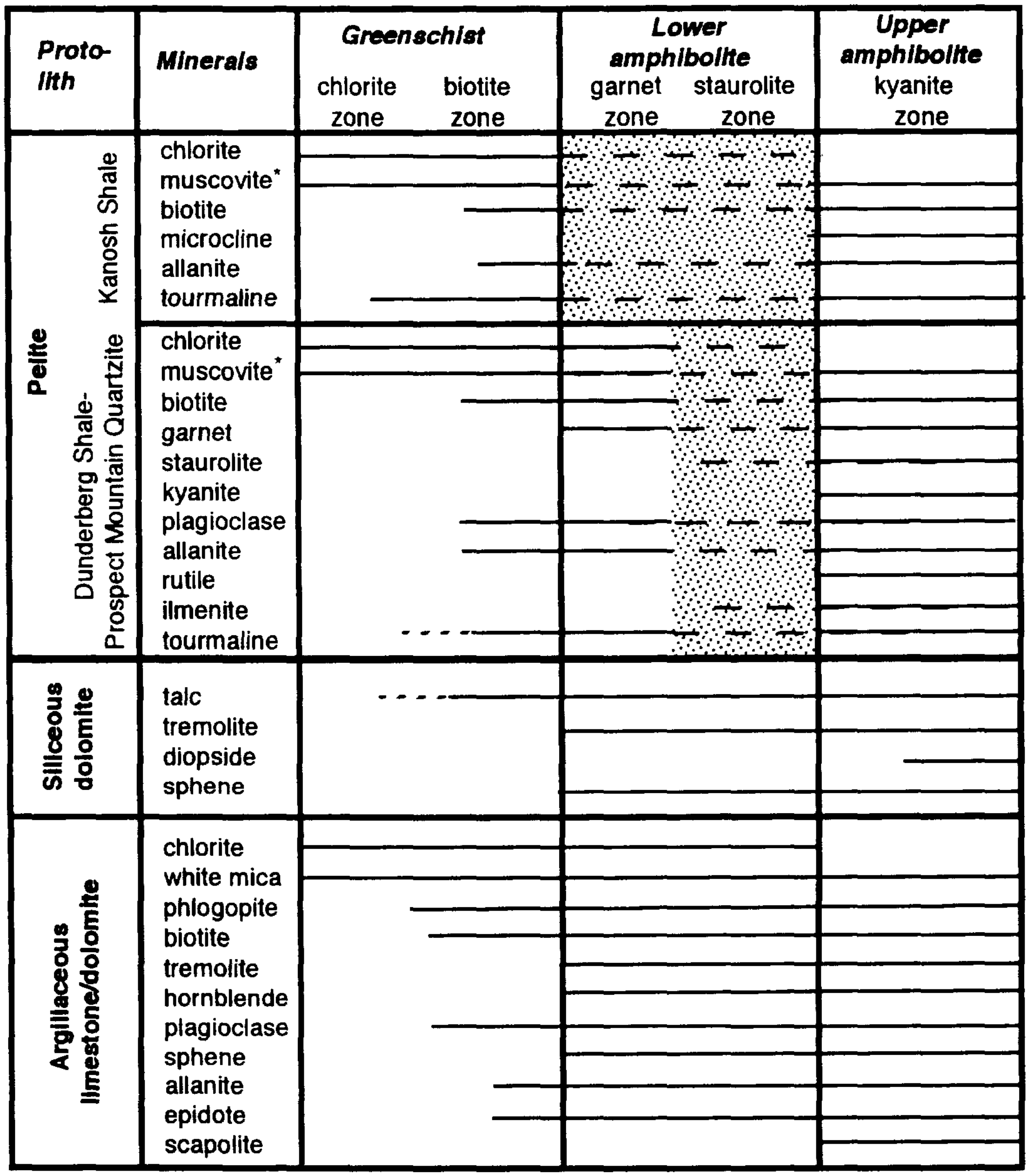


Figure 2.



* = sericite in the chlorite zone

Figure 3.

Metamorphic map of the Pequop Mountains

Metamorphic assemblages in the footwall of the Independence thrust

Prospect Mountains Quartzite
- spl 125A; Q-MU- BI-GT-PL-CHL (retrogressive rim around GT)

Killian Springs Formation (meta-carbonate)
- spl 43PA; TR-TLC-CC-Q
- spl 14P; TR-TLC-Q

Toano Limestone (meta-carbonate)
- spl 49P; BI-CC-HNB-Q-DO-CHL-SPH-ALL (rimmed by EP)

undifferentiated Cambrian strata (metapelite)
- spl 2AP; BI-MU-Q-CHL-PL-ALL-TOUR
- spl 73P; BI-MU-Q-CHL-TOUR

Dunderberg Shale (metapelite)
- spl 3AP; BI-MU-Q-CHL-PL-TOUR-CC-ALL (rimmed by EP)
- spl 8AP; BI-MU-Q-CHL-PL-ALL-TOUR
- spl 34PA; BI-MU-Q-EP-CHL-PL-ALL-TOUR

quartzite in the Pogonip Group
- spl 36P; CC-DO-Q

Kanosh Shale (metapelite)
- spl 23P; SER-CHL-TOUR

Metamorphic assemblages in the hanging wall of the Independence thrust

Toano Limestone (meta-carbonate)
- spl 152AP; TR-CC-DO

Dunderberg Shale (metapelite)
- spl 132PCA; BI-MU-Q-CHL-PL-CC-TOUR-ALL
- spl 81AP; BI-MU-Q-CHL-PL-ALL-TOUR
- spl 38AP; BI-MU-Q-CHL-pyrite-ALL-TOUR
- spl 155AP; Q-SER-CHL-PL(detrital?)

Figure 4.

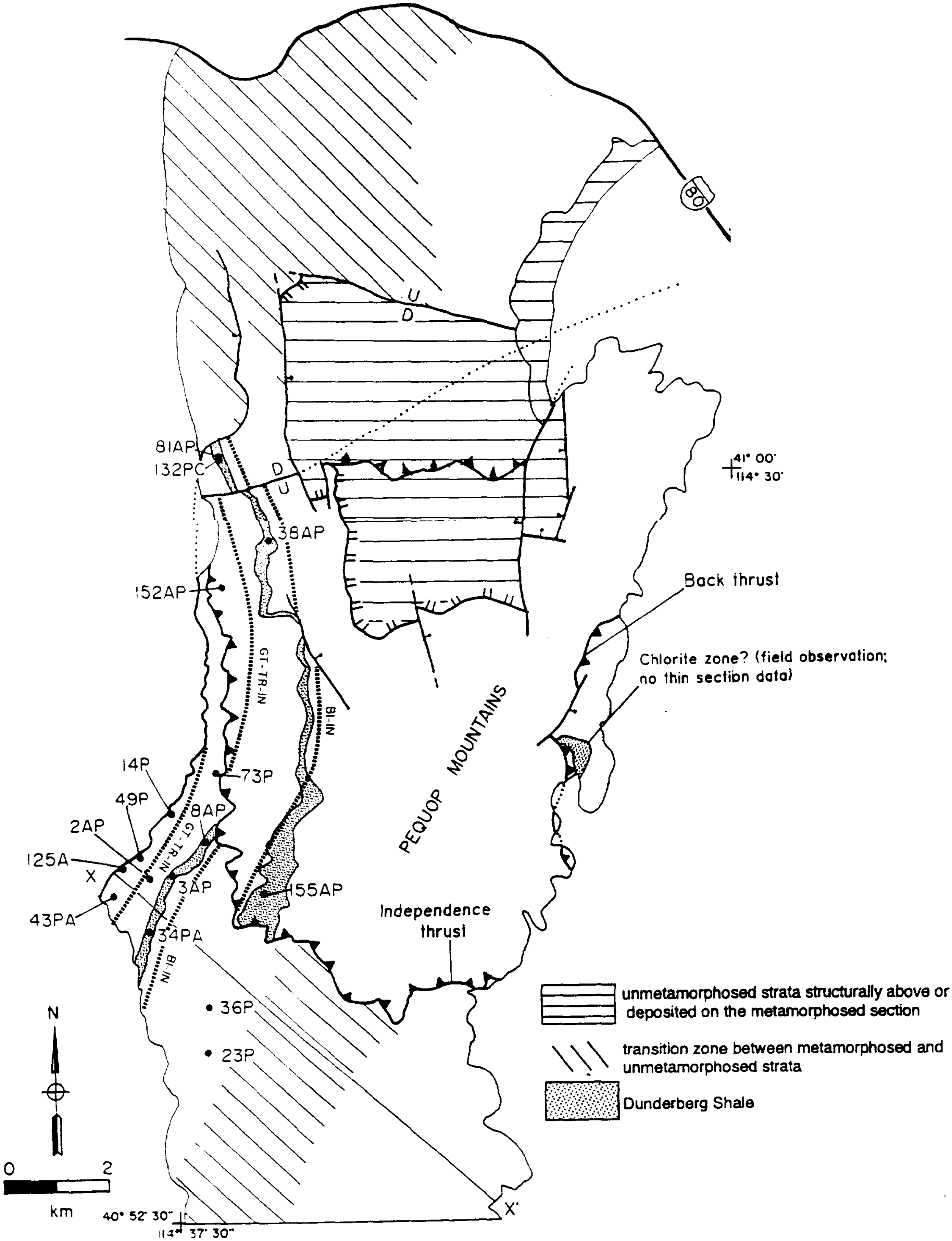

80
U
D
81AP
132PC
D
U
38AP
152AP
Back thrust
41° 00'
114° 30'
Chlorite zone? (field observation; no thin section data)
GT-TR-IN
BI-IN
PEQUOP MOUNTAINS
14P
73P
49P
8AP
2AP
125A
X
3AP
155AP
43PA
34PA
Independence thrust
36P
23P
N
0
2
km
40° 52' 30"
114° 37' 30"
X'
unmetamorphosed strata structurally above or deposited on the metamorphosed section
transition zone between metamorphosed and unmetamorphosed strata
Dunderberg Shale

Figure 4

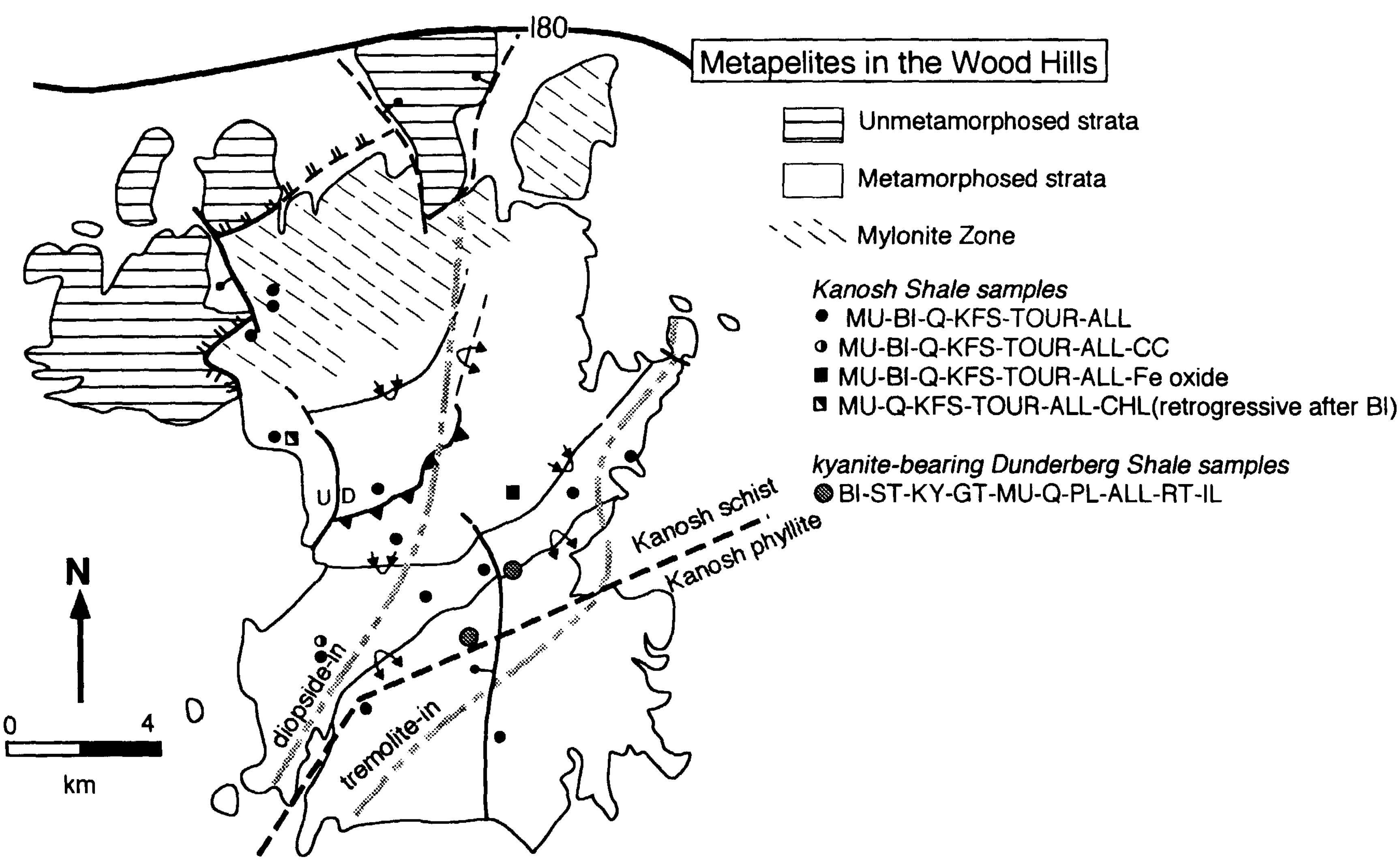
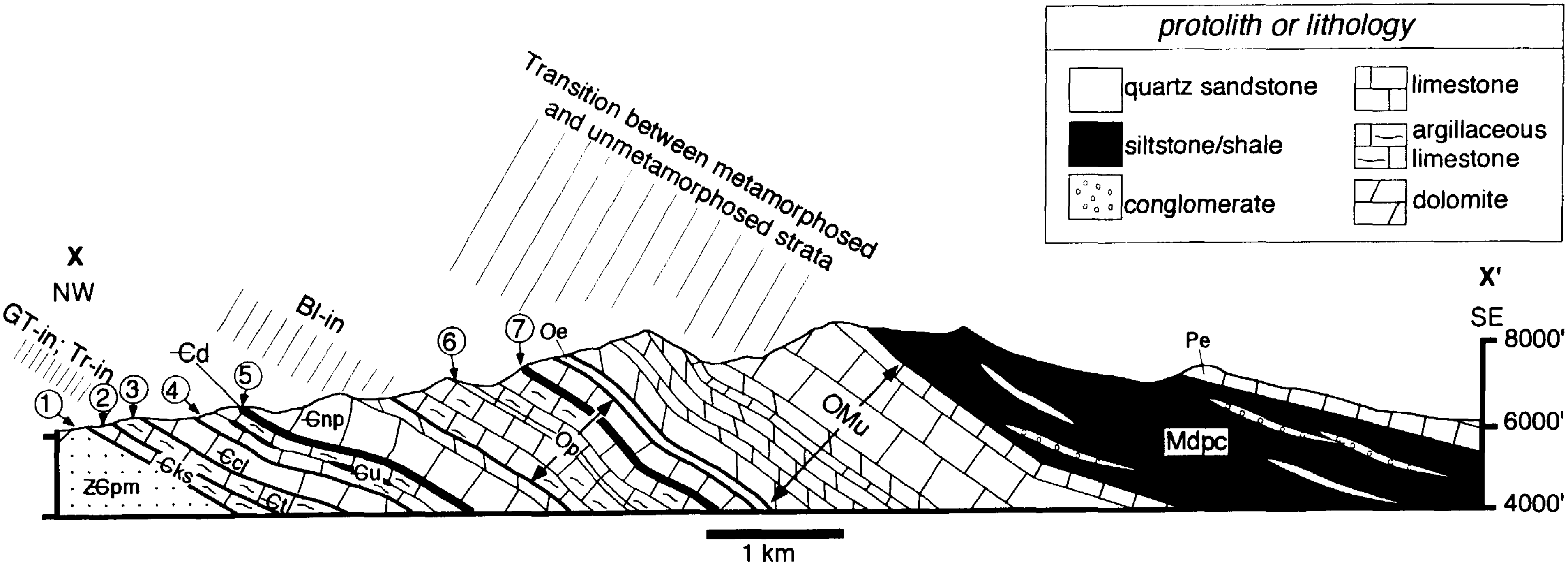

180
Metapelites in the Wood Hills
Unmetamorphosed strata
Metamorphosed strata
Mylonite Zone
Kanosh Shale samples
MU-BI-Q-KFS-TOUR-ALL
MU-BI-Q-KFS-TOUR-ALL-CC
MU-BI-Q-KFS-TOUR-ALL-Fe oxide
MU-Q-KFS-TOUR-ALL-CHL(retrogressive after BI)
kyanite-bearing Dunderberg Shale samples
BI-ST-KY-GT-MU-Q-PL-ALL-RT-IL
Kanosh schist
Kanosh phyllite
diopside-in
tremolite-in
U
D
N
0
4
km

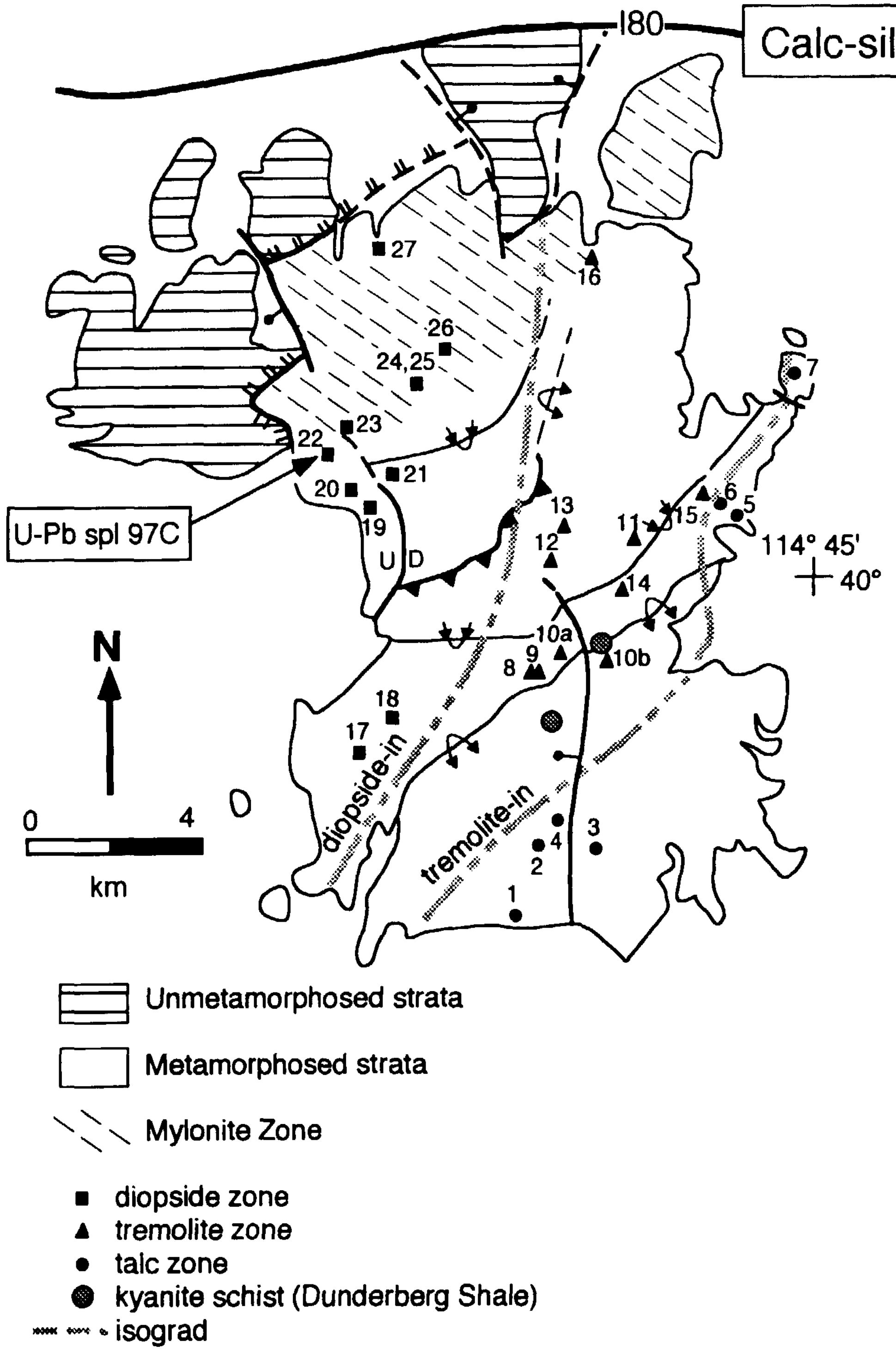
Figure 5



	Metamorphic Assemblages
lower amphibolite facies	(1) Z€pm (spl. 125AP; quartzite) Q-MU-BI-GT-PL-CHL(*retrogressive rim around GT*)
greenschist facies	(2) €ks (spls. 43PA and 14P; siliceous carbonate) TR-TLC-CC-Q TR-TLC-Q (3) €t (spl. 49P; impure carbonate) BI-CC-HNB-Q-DO-CHL-SPH-ALL(rimmed by EP) (4) €u (spls. 2AP and 73P; metapelite) BI-MU-Q-CHL-PL-ALL-TOUR BI-MU-Q-CHL-TOUR (5) €d (spls. 3AP, 8AP, and 34PA; metapelite) BI-MU-Q-CHL-PL-TOUR-CC-ALL(rimmed by EP) BI-MU-Q-CHL-PL-ALL-TOUR BI-MU-Q-EP-CHL-PL-ALL-TOUR (6) Op (spl. 36P; impure quartzite) CC-DO-Q (7) OP (spl. 23P; Kanosh Shale in the Pogonip Group) SER-CHL-TOUR

Figure 6. Camilleri and Chamberlain data repository

Calc-silicate assemblages in the Wood Hills



List of stable assemblages

Talc zone

(1) Simonson Dolomite, Q-DO
(2) Fish Haven Dolomite, Q-DO
(3) Fish Haven Dolomite, Q-DO
(4) quartzite in the Pogonip Group, CC-DO-Q
(5) quartzite in the Pogonip Group, CC-DO-Q-TLC
(6) Simonson Dolomite, CC-DO-Q-TLC
(7) Roberts Mountains Formation, CC-DO-Q-TLC

Tremolite zone

(8) Notch Peak Formation, TR-CC-DO
(9) Notch Peak Formation, TR-CC-DO
(10A) Notch Peak Formation,TR-CC-DO-Q
(10B) Notch Peak Formation,TR-CC-Q
(11) Simonson Dolomite, Q-DO
(12) Field observation of tremolite, no thin section
(13) Field observation of tremolite, no thin section
(14) Field observation of tremolite, no thin section
(15) Field observation of tremolite, no thin section
(16) Field observation of tremolite, no thin section

Diopside zone

(17) quartzite in the Pogonip Group, DI-CC-Q
(18) quartzite in the Pogonip Group, DI-TR-CC-Q
(19) quartzite in the Pogonip Group, DI-DO-Q
(20) Roberts Mountains Formation, DI-TR-CC
(21) Simonson Dolomite, DI-DO-Q
(22) Roberts Mountains Formation, DI-CC-DO
(23) Roberts Mountains Formation, DI-CC-Q

Diopside zone rocks overprinted in the mylonite zone

(24) Simonson Dolomite, various reactions breaking down DI to TLC, Q, CC, DO
(25) DI --> TR-CC-Q
(26) Simonson Dolomite, DI reacted out, and pseudomorphed by, TLC-DO-Q
(27) quartzite in the Pogonip Group, DI --> TR-CC-Q

Figure 7.

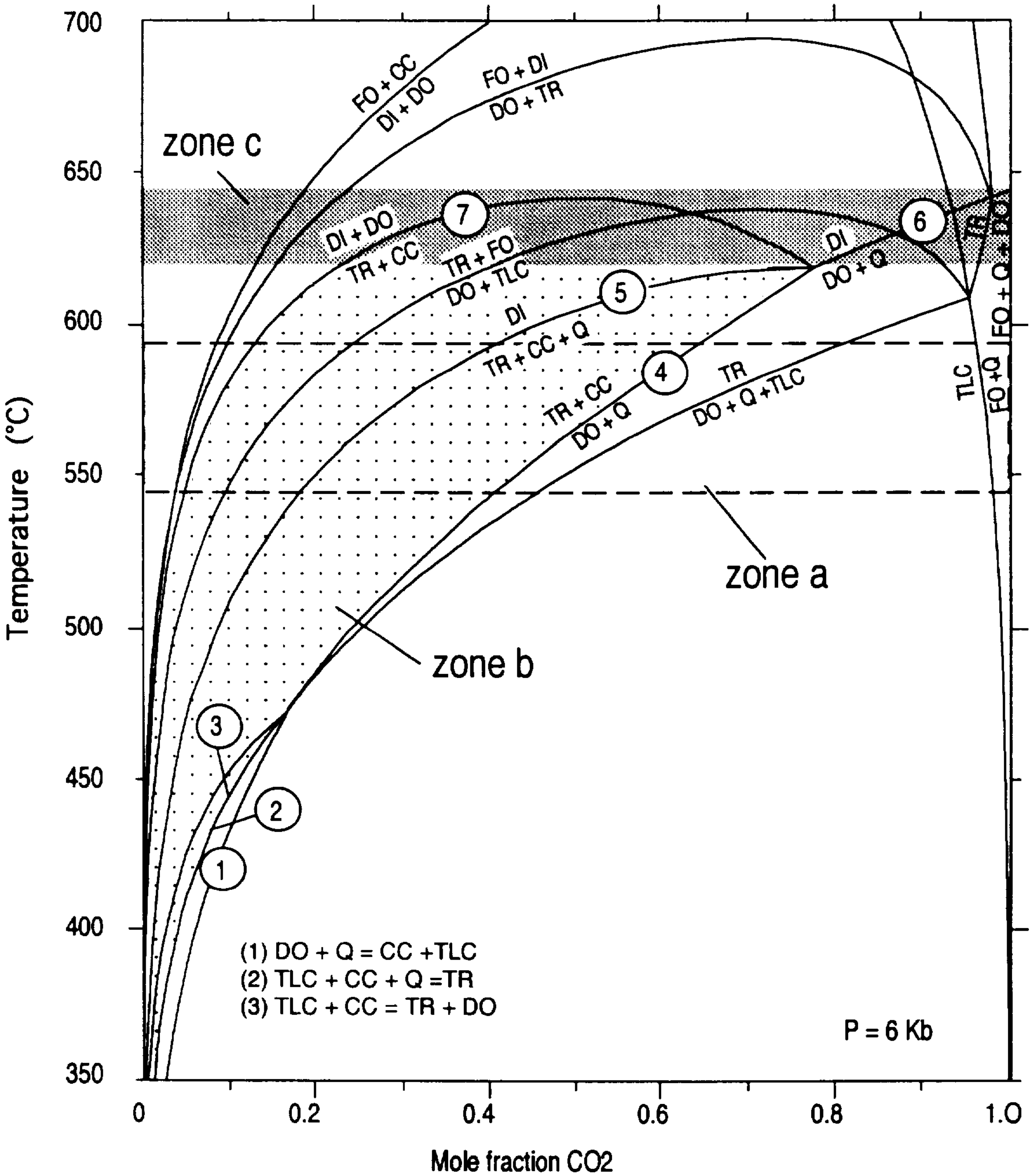


Figure 8. (Camilleri and Chamberlain; data repository)