

# **Text to accompany Arizona Geological Survey Digital Geologic Map DGM-89**

Geologic map of the Happy Valley 7 ½' Quadrangle, Cochise and Pima Counties, Arizona

scale 1:24,000

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## **Structural Geology**

Previous studies (Drewes, 1974; Lingrey, 1982), as well as this study, included measurements of various foliations and lineations in the penetratively deformed rocks of the eastern Rincon Mountains (see also Davis, 1980). All resulting data were compiled into a Microsoft Excel spreadsheet and plotted on equal-area, lower hemisphere stereonet using GEORient graphing and statistical analysis software developed by Rod Holcombe.

**San Pedro detachment fault.** Mylonitic foliation and lineation are associated with the San Pedro detachment fault only near the western edge of the Happy Valley 7 ½' Quadrangle. This is interpreted as a consequence of an east-to-west increase in paleodepth and corresponding paleotemperature during initial extensional shearing along the San Pedro detachment fault and its down-dip continuation as a mylonitic shear zone. Foliation and lineation measurements (n=10 and 11, respectively; Fig. 1A) indicate early extension oriented  $4^{\circ}$   $075^{\circ}$ . However, restoration of presumed regional eastward tilting associated with isostatic rebound of the fault footwall during Oligo-Miocene tectonic exhumation (e.g., Spencer, 1984) would result in gentle westward rather than eastward plunge for the lineations at the time of mylonitic shearing.

**Recrystallized mylonitic fabric.** Mapping of porphyritic biotite granite (map unit Ygp) both north and south of Happy Valley and in the footwall of the San Pedro detachment fault resulted in identification of a recrystallized mylonitic fabric. Stereonet analysis indicates a more steeply plunging and more northeasterly orientation for mylonitic lineation relative to mylonitic lineation associated with the San Pedro detachment fault (Fig. 1B). We conclude that these two fabrics are unrelated, and that the recrystallized mylonitic fabric is older.

**Wildhorse Mountain thrust.** The Wildhorse Mountain thrust fault is a major structure at the eastern edge of the Happy Valley Quadrangle where it places the Paleoproterozoic Johnny Lyon granodiorite over tectonized, primarily calcareous, Paleozoic strata. The Johnny Lyon granodiorite is mylonitized within several to several tens of meters above the thrust fault. The average trend of measured lineations is  $3^{\circ}$   $067^{\circ}$  (Fig. 1C). Sense-of-shear indicators, visible primarily in a canyon bottom at the southwesternmost exposure of thrust-fault mylonites, indicate top-northeast mylonitic shearing.

A displaced fragment of the Wildhorse Mountain thrust fault is exposed in the south-central part of the Quadrangle. This fragment is below the San Pedro detachment fault but above a subsidiary low-angle normal fault with evidence of crystal-plastic shearing where carbonate rocks are displaced. This semi-brittle – semi-ductile shear zone is part of a set of such shear zones that are numerous farther north, and that separate abundant carbonate and other metasedimentary tectonites from each other and from underlying, less deformed crystalline rocks. Foliations and lineations measured from displaced mylonitic rocks above the thrust fault (Fig. 1D) are similarly oriented as those at Wildhorse Mountain (Fig. 1C), but are tilted  $\sim 25^\circ$  to the east relative to the undisplaced mylonitic lineations, as expected for characteristic back-tilting above a top-west low-angle normal fault.

**All stereonet data.** Various foliation and lineation data, derived largely from new mapping but including data from Drewes (1974) and Lingrey (1982), were grouped by identified fabric type, geographic area, and data source, and are plotted in Figure 2 (BJJ = Brad Johnson; JES = Jon Spencer). All foliation groups dip gently to moderately and define a cluster with a general eastward dip. All lineation groups plunge gently and lie in the northeast or southwest quadrants. Fabrics are not well differentiated on the basis of orientation. Except for fabrics clearly associated with the San Pedro detachment fault and the Wildhorse Mountain thrust fault, it was not possible with available data to clearly differentiate deformation fabrics.

## **Geochemistry**

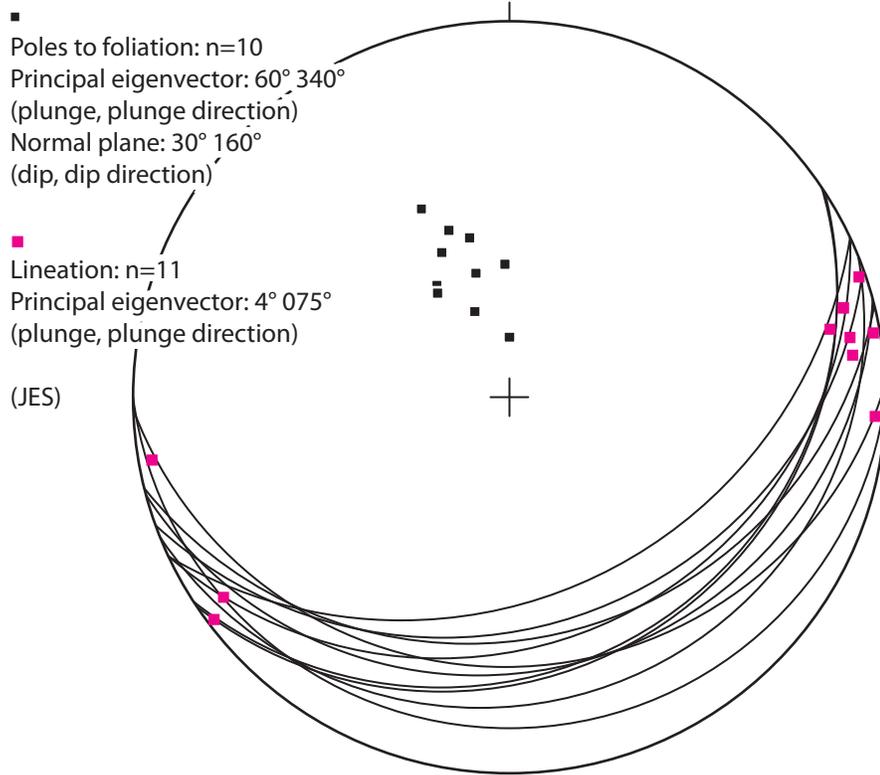
Hornblende meladiorite of map unit TJm consists of an  $\sim 2$ - $3$ -km-wide hornblende-rich holocrystalline intrusion in the center of the map area, and several small subsidiary intrusions and dikes. Hornblende is commonly the dominant mineral, and the unit includes hornblendite with greater than 90% hornblende and dikes with acicular hornblende phenocrysts up to 12 cm long. Biotite is present locally. Near the east edge of the quadrangle the unit intrudes Paleozoic carbonates, so the unit is known to be post-Paleozoic in age. However, a sample of the unit did not yield any zircons, and further constraints on age are lacking.

Because of the post-Paleozoic age of the unit, mafic composition, and regional location within the Bisbee rift belt (e.g., Dickinson and Lawton, 2001), it was considered possible that the unit is late Jurassic in age and was intruded in response to late Jurassic rifting that initiated deposition of the Bisbee Group. Previous geochemical analysis of basaltic rocks related to Bisbee rifting identified basalts with lanthanum/tantalum ratios of  $< 20$ , which is a known identifier for mafic igneous rocks unaffected by tectonic subduction and so unrelated to subduction-related magmatism (Lawton and McMillan, 1999; Spencer et al., 2011). Analysis of four samples of the hornblende meladiorite unit of Happy Valley identified La/Ta ratios of 21 to 46 (Table 1). We conclude that this unit is unrelated to Bisbee rifting and is likely the result of Laramide subduction-related magmatism.

## References cited

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**A** Mylonitic foliation and lineation associated with the San Pedro detachment fault, Happy Valley northwest



**B** Recrystallized mylonitic foliation and lineation primarily in Oracle Granite (Ygp)

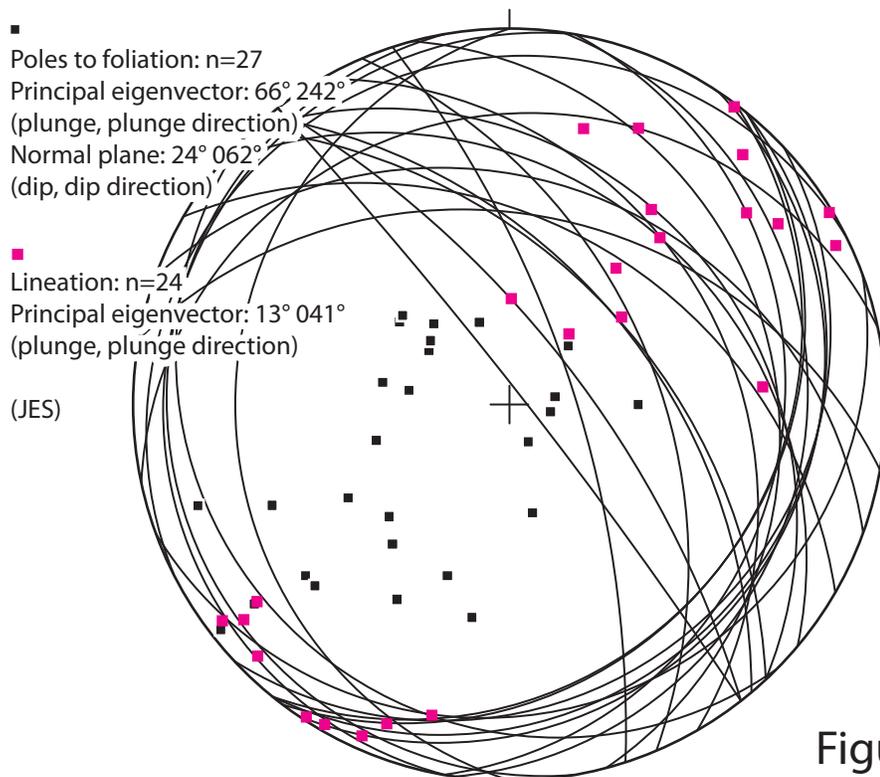
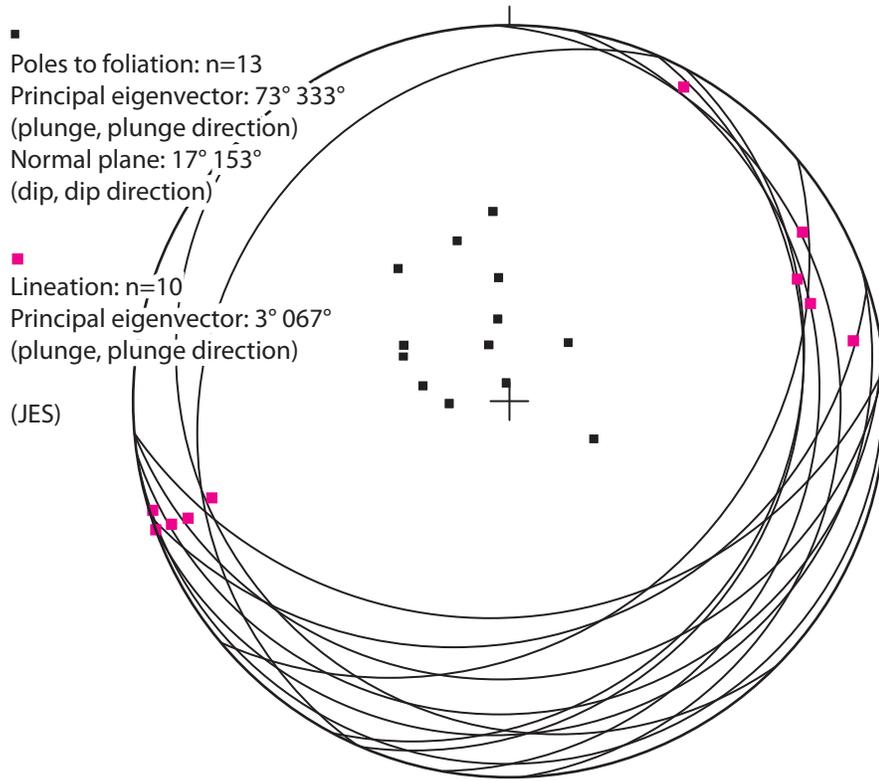


Figure 1 (A, B)

**C** Mylonitic foliation and lineation associated with the Wildhorse Mountain thrust fault, Happy Valley southeast



**D** Mylonitic foliation and lineation associated with the Wildhorse Mountain thrust fault, displaced segment, Happy Valley south

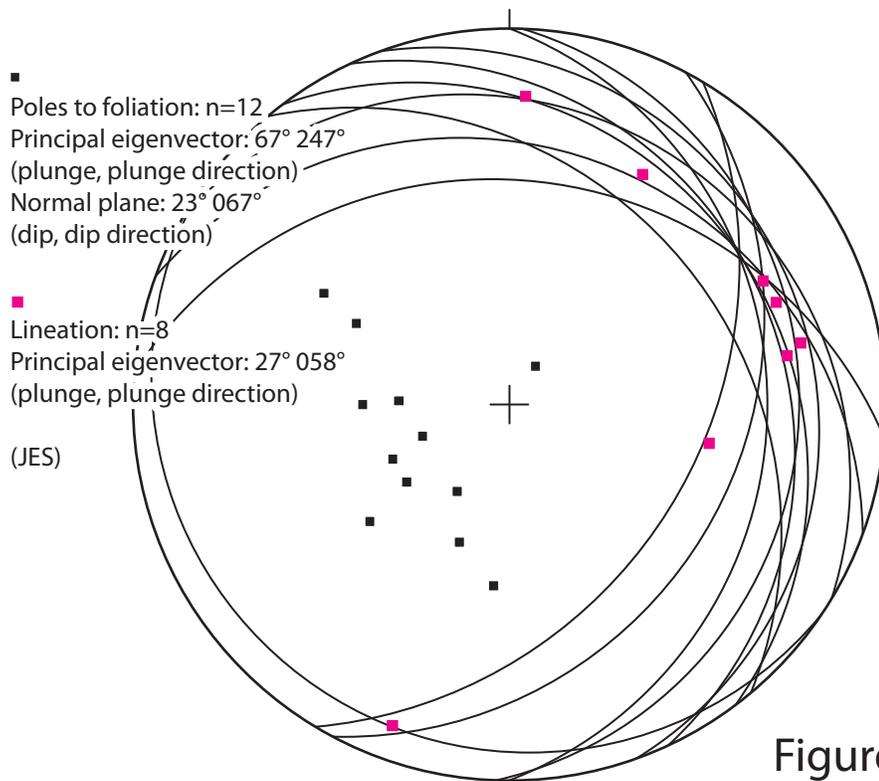


Figure 1 (C, D)

## All foliation and lineation groups, Happy Valley Quadrangle

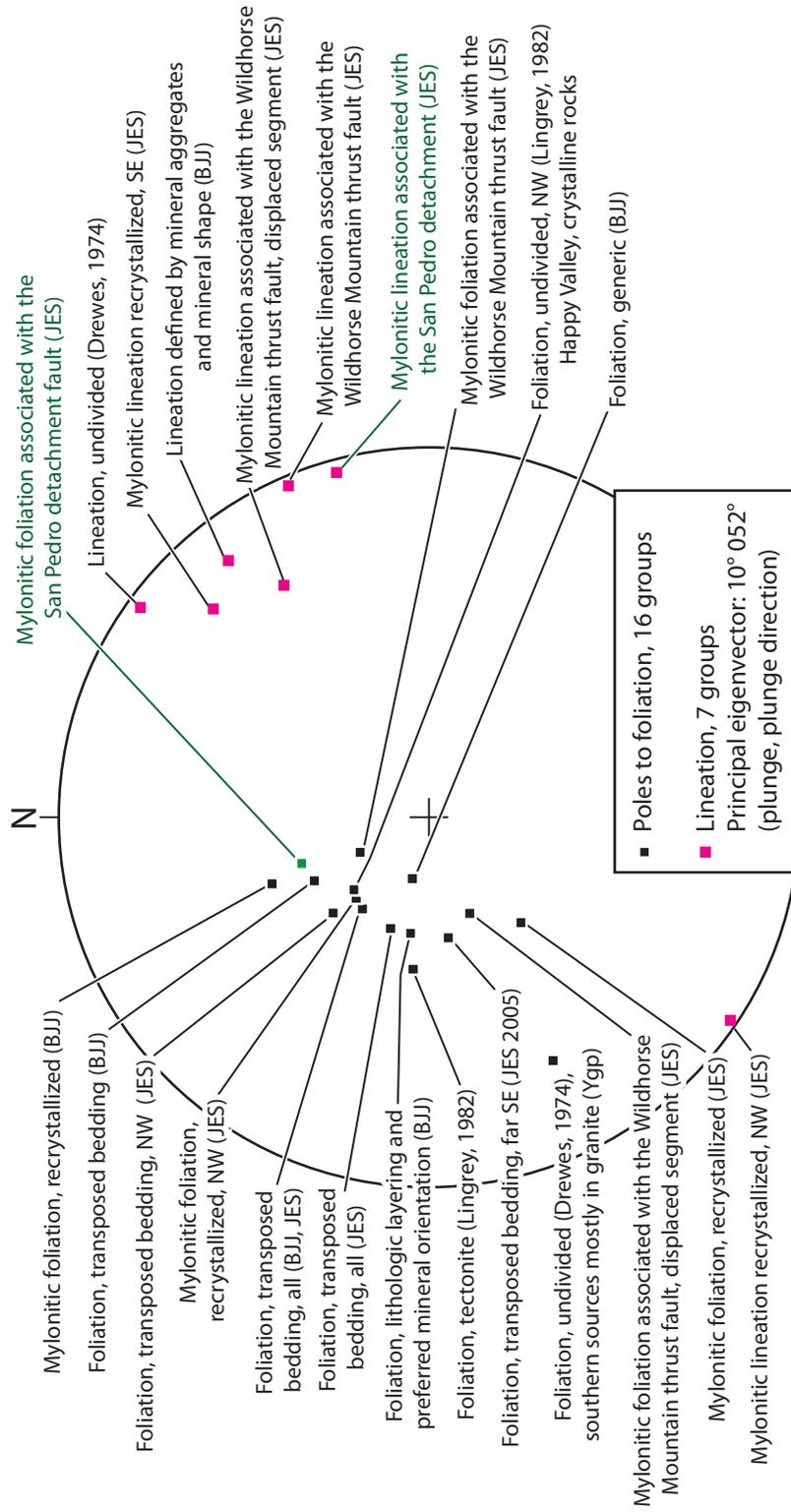


Figure 2

