
THE DRY UNION FORMATION IN HOWARD, CO: DOCUMENTING THE SANGRE DE CRISTO UPLIFT

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INTRODUCTION

Following the Cretaceous to early Tertiary Laramide Orogeny in central Colorado, the Laramide mountain ranges underwent a period of erosion and related deposition that led to the formation of a low-relief landscape known as the Eocene erosion surface (Epis and Chapin, 1975). The evolution of modern rugged landscape of the present-day Rocky Mountains is currently under debate and of considerable research interest (Steven, et al., 1997; Gregory and Chase, 1994; Chapin and Cather, 1994). The Howard Paleovalley is a post-Eocene depositional basin, filled with coarse clastic sediments of the Dry Union Formation (Taylor et al., 1975) that offers a superb site for investigation of the evolution of the Sangre de Cristo Range. The clastic sediments potentially record the growth of the adjacent mountain uplift, with possible time control offered by interstratified volcanic tephra. The depocenter spans a time of reorganization of the river drainages from NW-flowing during the Eocene to SE-directed in the modern systems.

Regional Background

Elevation and degree of relief along the Eocene surface are heavily debated; different models favor either regional uplift or climatic changes as the primary mechanism for post-Eocene denudation and potentially rapid evolution of the current landscape (Steven, et al., 1997; Gregory and Chase, 1994). Gregory and Chase (1994) propose high elevation/low relief,

attributing later incision to climatic factors. Steven et al. (1997) suggest that relief varied from low (< 300 ft) to mountainous (>1000 ft), but that low relief prevailed in areas underlain by Paleozoic sedimentary rocks, such as the Howard Paleovalley. These areas remained at low relief into the early Oligocene when south-central Colorado experienced an interval widespread volcanism. Pyroclastic deposits were transported and deposited in many of the drainage systems established during the late Eocene.

The youngest ash flows within the Howard Paleovalley occur near Kerr Gulch (Fig. 1) and have been identified as Fish Canyon Tuff (27.9 Ma) and Carpenter Ridge Tuff (27.4 Ma) using $^{40}\text{Ar}/^{39}\text{Ar}$ tephrochronology (McIntosh and Chapin, 2002). These dates provide a maximum age for clastic sedimentation in the Howard Paleovalley. McIntosh and Chapin (2002) have linked both tuffs to volcanic centers in the San Juan Volcanic Field to the southwest. These findings confirm a model by Epis et al. (1976) depicting Oligocene to early Miocene paleovalleys trending northeast. The middle Tertiary drainage pattern contrasts with the modern Arkansas River Valley and other drainages in the area that trend to the southeast.

The northeast-trending paleovalleys were disrupted when the Rio Grande Rift system propagated northward and the Sangre de

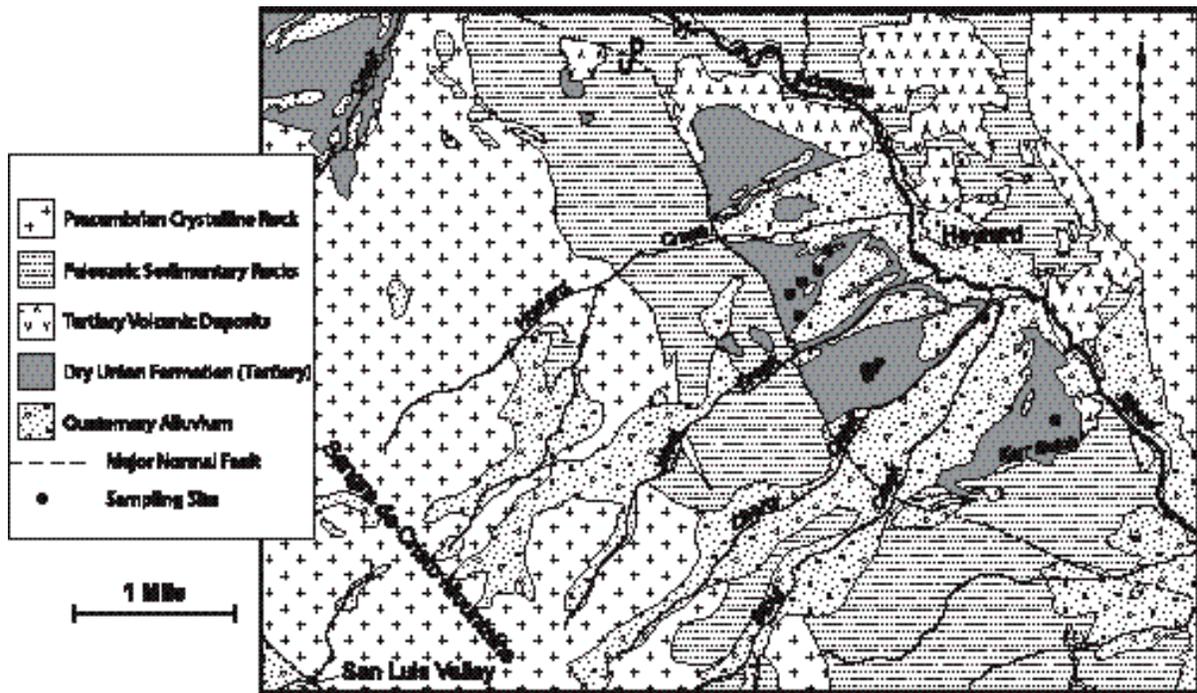


Figure 1. Simplified geologic map of the field area, west of Howard, Colorado (after Taylor, et al., 1975). The Sangre de Cristo Mountains are labelled along the ridge line.

Cristo Mountains were uplifted (Epis et al., 1975). Northwest-trending normal faults bounding the northern Sangre de Cristo Range created a Tertiary depositional center in the area west of Howard, CO, (see Fig. 1) which received over 1 km of coarse clastic sediments, mapped as the Dry Union Formation (Taylor et al., 1975). By the late Miocene, the Howard Paleovalley had assumed a northwest-southeast orientation, roughly parallel to the current Arkansas River (Taylor et al., 1975).

Rifting in the northern Rio Grande Rift may have begun as early as 28.8 Ma (Chapin and Cather, 1994). The precise timing of the uplift of the Sangre de Cristo Range (SDC) is unclear. Northwest of Howard in the Upper Arkansas Valley, an axial basin of the Rio Grande Rift, Hubbard, et al. (2001) found $^{40}\text{Ar}/^{39}\text{Ar}$ ages from 14.2 Ma to 8.5 Ma for two groups of volcanic ash layers within the Dry Union Formation near Salida, CO. Howard is located along a peripheral basin of the rift, and $^{40}\text{Ar}/^{39}\text{Ar}$ ages for ashes within the sediments of the Howard Paleovalley can help to establish the spatial variability of rifting and associated uplift.

DESCRIPTIVE ANALYSIS

Sedimentology

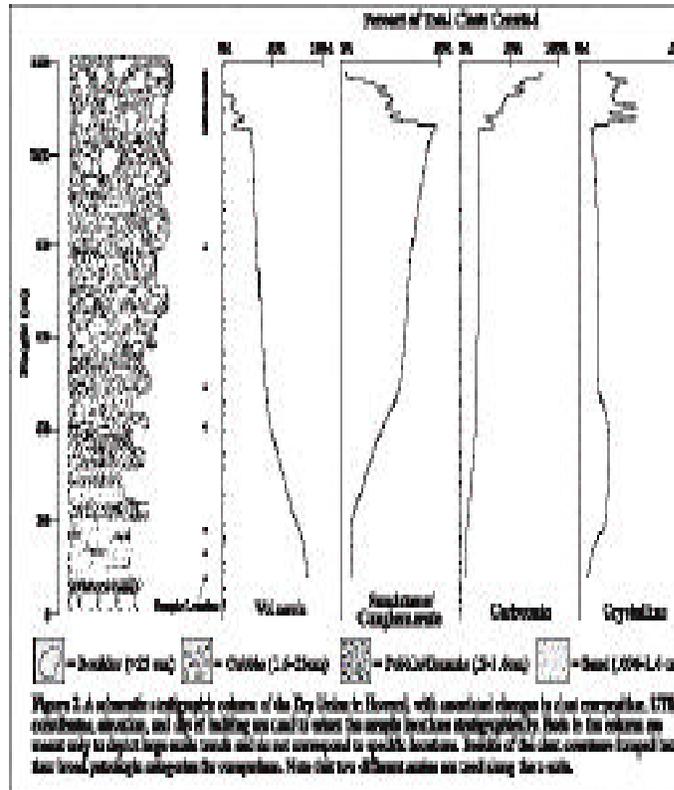
The Dry Union Formation in Howard occurs over a 35 km² area, most of which is covered by Quaternary alluvial deposits or obscured by slumping and poorly developed soils. Dry Union outcrops are restricted to current drainage systems in which recent incision has occurred. Beds in the lowest 200 m range in thickness from 0.1 to 2 m and are composed of fine sands and well-rounded pebbles (Fig. 2). The middle and uppermost sections contain poorly sorted, coarse clastic sediments, from sand to boulder size (Fig. 2), and beds of between 0.3 m and 2.5 m in thickness. Thirty-seven bedding orientations were measured throughout the area to be used with GPS data and elevation to establish a composite stratigraphy for the entire field area. Beds consistently dip between 17° and 26° to the southwest, striking between 96° and 143°. Orientations of aligned clasts were measured in certain beds where imbrication was apparent. Average imbrication directions from within single beds range from 27° to 69°, suggesting a paleocurrent toward the northeast.

The proximity of the Howard gravels to the adjacent high peaks of the Sangre de Cristo

Range suggested relatively local sources to the west for coarse, sub-angular clasts in the middle and upper strata. If the Dry Union was deposited during Sangre de Cristo uplift, dominant clast compositions may change temporally, as new units were brought to the surface and eroded. In order to identify trends in clast composition that might reveal changes in source rock, 21 clast counts were conducted throughout the field area. In each case, 100 clasts were counted within a designated area and divided into 20 petrologically distinct groups. The diameters of the largest five clasts within well-cemented beds of the higher sections were measured in place for comparison with grain size analyses of poorly consolidated beds in the lower strata. The highest beds include clasts up to 62 cm wide, while the coarsest beds in lowest 200 m (Fig. 2) contain clasts up to only 8 cm wide, though most beds contain no grains larger than 4 mm.

Tephrochronology

The lowest stratigraphic section of the Dry Union in Howard lies just south of Howard



Creek (Fig. 1). This section contains many beds of entirely fine-grained sand to silt, as well as gravel beds with rounded to well-rounded pebbles and small cobbles. These beds indicate

a lower energy depositional environment than that of the upper beds, with transport over a longer distance. The abundance of volcanic clasts suggests a subdued paleolandscape covered in volcanic deposits, consistent with the proposed Eocene surface (Gregory and Chase, 1994). Three fine-grained volcanic ash layers were discovered within this section, ranging in thickness from .04 m to 1.5 m. Samples of each were collected from the lowest portions of the beds, where the ash had not been reworked after initial deposition. William McIntosh at New Mexico Tech is performing $^{40}\text{Ar}/^{39}\text{Ar}$ tephrochronology on individual grains of biotite in two of these ash layers. Initial tests on sanidine grains proved inconclusive due to the presence of detrital sanidine that was not related to the initial eruption.

INTERPRETATIONS

Provenance

Moving up-section in the Dry Union Formation west of Howard, clast count data depict a shift from predominantly volcanic to sedimentary and crystalline clasts (Fig. 2). The crystalline clasts are mostly gneissic amphibolites and granitoids in the upper strata, and occur predominantly as generic quartz pebbles down-section. There is more variability in clast percentages in the upper 150 m of the section, where there is better exposure and more data were collected (Fig. 2). The middle and lower strata most likely contain the same variability, but fewer data limit the detail of the trend line, in a behavior known as aliasing.

Table 1 lists the four general clast categories and their closest probable source units based on reconnaissance mapping by Taylor et al. (1975). The relative ages and geographic distributions of the units in Table 1 indicate a reverse stratigraphy, in which the oldest clasts can be found in the youngest beds. The reverse stratigraphy suggests an unroofing sequence through Tertiary and Paleozoic rocks, down into Precambrian crystalline rock, driven by the development of relief associated with northwest-trending normal faulting (Fig. 1).

Depositional Setting

A coarsening-upward trend is evident in the ~1.2 km of Dry Union gravels near Howard (Fig. 2). The transition between the fine-grained lowest section and the coarse clastic middle to upper strata is obscured, but can be confined to within ~100 m of section. The increase in clast size upsection implies an increase in sediment transport energy (Rachocki, 1981). Although climatic change effects can't be ruled out, this increase can probably be attributed to a growing topographic gradient related to large offset along major normal faults bounding the northern Sangre De Cristo Range (Chapin and Cather, 1994).

The upper strata suggest that much of the Dry Union was deposited as alluvial fan. Poorly sorted beds containing both angular to sub-angular boulders and sub-rounded to rounded pebbles suspended in fine-grained matrices suggest debris flows as the dominant mode of transport (Rachocki, 1981). Beds showing consistent imbrication indicate highly fluid debris flows (Rachocki, 1981) towards the northeast. This finding indicates alluvial deposition to the northeast, off the Sangre De Cristo Range.

CONCLUSIONS

The Dry Union Formation in Howard contains an unroofing sequence that links deposition to the uplift of the northern Sangre de Cristo Mountains. Hubbard et al., 2001 have found 8.5-10.5 Ma ashes interbedded with Dry Union sediments in the upper Arkansas River Valley, but the 27.4 Ma Carpenter Ridge Tuff remains the only maximum time constraint for the Dry Union in Howard. $^{40}\text{Ar}/^{39}\text{Ar}$ dates of two volcanic ash layers within the lower gravels in Howard may help to refine the maximum age for the deposition of the coarse middle and upper strata. This would help to constrain the age of initial development of mountainous relief to the west, and the subsequent extinction of the NW-trending Howard Paleovalley. Further investigation of the ash layers and volcanic clasts within the lowest sections of the Dry Union in Howard are recommended for tightening time constraints on northern Sangre de Cristo uplift.

Table 1. Clast categories with probable source units.

Category	Geologic Unit(s)	Age
Volcanic	Wegah Mountain Andesite ↓ NW Mountain Tuff	Miocene ↓ Oligocene
Basaltic/Andesitic/ Conglomerate	Minturn & Rabbit Formations	Pennsylvanian
Carbonate	Landyville Limestone	Lower Mississippian
Crystalline	Granodiorite, Metagabbro and Gneiss	Proterozoic

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