CENOZOIC BASIN GEOLOGY AND GEOPHYSICS, SOUTHWESTERN MONTANA

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Cenozoic Basin Geology and Geophysics, Southwestern Montana

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INTRODUCTION

Southwestern Montana includes a network of intermountain basins which are part of a belt of Cenozoic crustal extension that extends from British Columbia to Utah. Many of these basins are half grabens formed by the extensional collapse of the Cordilleran fold and thrust belt beginning in the late Paleogene (Constenius, 1996). These basins are characterized by extensional reactivation of thrust faults. Other basins in the region appear to be controlled by reactivation of older high angle faults. This reactivation has been interpreted both as primarily dip-slip motion (Schmidt and Garihan, 1986) and as strike-slip motion (Ruppel, 1993).

These basins are filled with Cenozoic continental sediments. The majority of surface mapping of these sediments is based on lithostratigraphic units (Fields *et al*, 1985). This lithostratigraphy is difficult to apply due to rapid lateral changes and vertical repetition of lithologies (Hanneman and Wideman, 1991). More recently, sequence stratigraphy has allowed for improved mapping and correlation of this basin fill (Hanneman and Wideman, 1991). This application of sequence stratigraphy is made possible in part by seismic reflection data which allows for the identification of basin wide, sequence-bounding unconformities.

Because subsurface fluid flow in these basins is controlled by the stratigraphy, sedimentology and structural geometry, a clear picture of these elements is needed to address environmental questions in the region. These environmental issues include remediation efforts at EPA Superfund sites, siting and management of municipal landfills, and management of local watersheds for public and agricultural use. The goal of the 1996 Keck Montana project was to apply both geologic and geophysical methods toward a better understanding of the structure and stratigraphy of these basins.

PROJECT SYNOPSIS

Students arrived in Butte on 15 July, 1996. The project was based out of Montana Tech in Butte, with students and faculty housed on campus. Classrooms, laboratories and other facilities and equipment were provided by the Department of Geophysical Engineering. The faculty consisted of Glenn C. Kroeger and Walter W. Coppinger from Trinity University, Debra Hanneman from the Whitehall Geogroup Inc in Whitehall Montana, and Sherilyn Williams-Stroud from the U. S. Geological Survey in Denver Colorado.

The first day was spent in the Butte and Deerlodge valleys to the west of Butte (Figure 1.) visiting outcrops of the Tertiary basin fill and the underlying Boulder Batholith and associated volcanics. The second day was spent visiting the county landfill in Anaconda, and the EPA Superfund listed Rocker Site on the western outskirts of Butte. Both of these sites were ultimately chosen for student projects. The second two days were spent east of Butte in the Jefferson and Whitetail valleys. Additional Tertiary outcrops including vertebrate fossil sites were visited. An afternoon was spent with Bill Elliott and Bruce Douglas from Indiana University in the vicinity of Harrison on the east side of the Tobacco Root mountains. This area would later be the site of gravity and refraction seismic projects. Friday was spent touring the Golden Sunlight Mine in order to understand the economic, geologic and environmental issues which control the operations of a modern open-pit gold mine.

The second week was primarily devoted to selecting and defining projects for each student. Projects were ultimately selected in four areas, Anaconda, Rocker, Bull Mountain at a site west of the Golden Sunlight Mine, and the Harrison area. Weeks three and four were dominated by data collection at all four areas, although the Rocker project completed data collection in the third week and spent most of the last two weeks on processing of reflection seismic data.

Weekend activities included field trips to the Tobacco Root mountains, and a one-day mad dash through Yellowstone and Grand Tetons National Parks. Students left Butte on 14 August.

Visiting faculty included Cathy Manduca (Keck Consortium, 4 days), Robert Burger (Smith College, 4 days), Richard Stenstrom (Beloit College, 4 days), and Jan Wolf (Southwestern Louisiana University, 14 days).

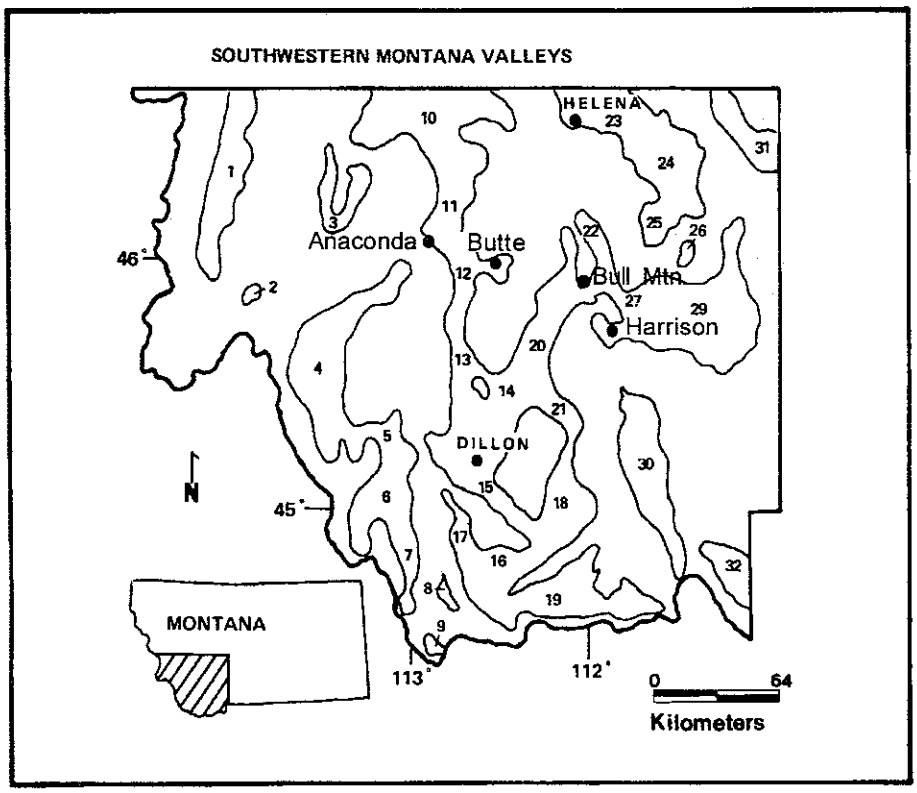

Figure 1. Location map of southwest Montana (after Hanneman and Wideman, 1991) showing the sites investigated during the 1996 Keck project and major valleys with Cenozoic basin fill.

STUDENT PROJECTS

Due to the nature of geophysical surveys, most students worked in groups during the data acquisition portion of their projects. Individual student projects involved the analysis of different portions of the collected data, or a focus on different aspects of data interpretation.

Rocker. The Rocker Timber Framing and Treating Plant operated from 1909 to 1957. This facility treated timbers for use in underground mines using creosote and arsenic solutions. Spillage of these solutions during operations and improper storage after the plant closed have resulted in soil contamination and an arsenic plume in the local shallow aquifer. In 1983 this site became an Operable Unit of the Silver Bow Creek Superfund site listed on the National Priorities List.

Four students worked on reflection seismic profiling at the Rocker site, five miles west of Butte. These students were Dan Fieveson (Carleton College), James Sneeringer (Beloit College), Erika Hammar-Klose (Smith College) and Jon Conaway (Montana Tech). This group was supervised by Debra Hanneman. The goal of this project is to delineate the Quaternary-Tertiary interface and clarify the structure of the Tertiary fill under this site. Groundwater contamination in the shallow Quaternary aquifer has the potential of migrating to the deeper Tertiary aquifer here. This migration could be facilitated by the possible existence of the Rocker fault, a northward extension of the basin bounding fault which is clearly mapped south of Rocker. It is hoped that the detailed seismic profiles and resulting interpretation in geologic cross-sections will indicate whether this fault exists and extends under the Rocker Site.

The students working on the Rocker site were able to acquire 12-fold seismic reflection data during the first two weeks of the project. Four separate, but intersecting lines were shot at the site. This group spent most of the remainder of the time learning to process multifold reflection seismic data using the WinSeis package from the

Kansas Geologic Survey. By the end of the four weeks, an initial zero-offset seismic section of the longest line had been constructed. In addition, the group spent time reading and discussing existing reports on the geology of the site, surveying the location of shot points, and field checking and modifying geologic maps of the Rocker site and surrounding areas. On returning to their home institutions, each student has continued to process the seismic data and has applied the data to a different aspect of the interpretation of the geology of the Rocker site.

Anaconda. Two students choose projects at Anaconda, Montana, 30 miles west of Butte. Both projects deal with the geologic setting of the landfill at the western edge of the Deerlodge Valley. Karen Foster (Smith College) choose to do a detailed geologic map of a four square-mile area of the Warm Springs Creek watershed in which the landfill was developed. Karen carried out traditional geologic mapping as well as soil sampling and trenching. Hugh Dresser of Montana Tech also flew Karen over the Anaconda site and assisted her in taking traditional oblique airphotos as well as stereo airphoto pairs. Karen's work has resulted in a geologic map and an interpretation of the aquifer system in this area.

Katie Lethenstrom (Whitman College) choose to work on an active slump on the east face of the Deerlodge valley, east of the area that Karen was mapping. This slump was induced by removal of borrow material by ARCO from the base of the valley wall. Katie carried out repeated surveys of existing reference points as well as an array of new reference points which she staked out on the slump. These surveys were done with a digital total station. In addition to the surveys, Katie did detailed mapping of the slump including the documentation of active movement through observations of changes in crack widths and the development of slickensides on fresh slip surfaces. Katie has used her survey data, along with data from ARCO, to produce a map of displacements in the slump block and an analysis of the ongoing development of the movement.

Bull Mountain. Heather Schweninger (Washington and Lee University) choose to work on the geology of the western side of Bull Mountain, the site of the Golden Sunlight Mine. Her goal was to use geophysical surveys to refine the interpretation of the geology and basin bounding faults at this location that are covered in part by a Quaternary pediment surface. Heather carried out detailed field mapping. With the help of the students involved at the Rocker site, two long seismic refraction lines were shot across suspected fault zones. Heather also surveyed and measured four gravity lines. Heather's work has resulted in the location of several buried faults.

Harrison. On the east side of the Tobacco Root mountains, in the vicinity of Harrison, Montana, Cenozoic basin fill underlies much of the Willow Creek watershed. It is unclear whether these sediments represent the edge of either the Madison Basin to the south, the Three Forks Basin to the north, paleovalley fill unrelated to either basin, or a separate smaller basin (Douglas, 1996). Four students choose to use gravity surveys constrained by refraction seismic profiles to investigate the geometry this basin. This area is currently being mapped by Bill Elliott, a MS student at Indiana University as a Geologic Mapping Education component of the National Cooperative Geologic Mapping Program of the U. S. Geological Survey. The Willow Creek watershed is also the site of ongoing hydrology studies being conducted by IU. April Hoh (Trinity University), Carter Gehman (Colorado College), Sarah Peugh (Colorado College) and Kyle Kolodziejski (Beloit College) worked on this project. Over 30 km of gravity lines were surveyed, with station spacing ranging from 100m to 250m. In addition, six seismic refraction lines were shot at critical locations along the gravity lines.

Preliminary interpretation of the data suggests a deep graben north of Harrison with offsets of up to 1000m on the northermost fault boundary of the basin. The remaining boundaries appear to be onlap of Cenozoic sediments onto the surrounding Precambrian basement. Carter and Sarah have concentrated on the interpretation of the main north-south gravity line and accompanying seismic lines. Kyle's work focuses on the nature of the basin margin near a test well drilled by IU. April's work involves carrying out terrain corrections with DEM data and analyzing the overall gravity anomaly of the basin in two dimensions with the goal of determining what part of the observed regional gradient is due to the topography of the Tobacco Root mountains.

ACKNOWLEDGMENTS

The project was enhanced by the contributions of many individuals from the Butte area. Hugh Dresser of Montana Tech gave an outstanding 3-D slide presentation on the geomorphology of southwestern Montana and took one student aloft for a morning of airphoto acquisition. Charles Wideman of Montana Tech provided valuable assistance on geophysical techniques and analysis as well as information on local fishing conditions.

Mark Pokorny and Mike Lasher from ARCO and Ron Milam of DJ&A surveying assisted in work on an active slump at the Anaconda Site. Chuck Stillwell of ARCO was our contact for work at the Rocker site.

Bill Elliott of Indiana University provided daily updates of his field mapping results, without which the work at Harrison would not have been successful. Bill also sacrificed his car in service to our cause. Bruce Douglas, Greg Olyphant and Lee Suttner, also from Indiana University, provided valuable insights and assistance.

Jack Truckle, mine geologist at the Golden Sunlight Mine lead our tour and provided supporting materials. We are also indebted to Jerry Harrington, mine manager of the Golden Sunlight Mine.

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The Use of a Shallow Seismic Reflection Profile as an Aid in Groundwater Model Development at the Rocker Timber Framing Treatment Plant Operable Unit Rocker, MT

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Introduction

Shallow seismic reflection profiling was helpful in the development of a groundwater flow model at the Rocker Timber Framing Treatment Plant Operable Unit (RTFTP/OU). Evaluation of drillers logs, well cores, and field mapping defined the major hydrogeologic units at the site.(ARCO,1995; Hydrometrics Inc., 1988) Two major hydrogeologic units exist at the site; an upper unit is composed of unconsolidated alluvial material, and a lower unit consisting of mixed Tertiary age clays, silts, and gravels. Although numerous wells exist on or near the site, only one was completed within the interpreted Tertiary horizon. A seismic reflection profile was used to establish the thickness and structure of the underlying Tertiary materials.

Data Acquisition

The seismic data used for this project were recorded using a standard common midpoint (CMP) roll along method. The line used was laid out using 48 takeouts, 24 being used for recording each shot. A five meter station spacing was used for receiver stations. The receiver groups consisted of a 2.5 meter in line array of three 40 HZ geophones overlapping at each takeout. The lines were shot off end with the shot stations moving forward by five meters each shot. Four lines were shot in all. The source for the line was a 16 pound sledge hammer and a metal strike plate. Stations were surveyed with a Philadelphia rod and level. A 24 channel Bison model 9024 seismograph was used to record the data. Table I. shows the recording parameters used to acquire the data.

Table I. Recording Parameters

Station Spacing	5 meters
Record Length	500 ms
Sample rate	1 ms
High cut filter	120 HZ
Low cut filter	32 HZ
Field summing	9 shots

Data Processing

One of the keys to successfully processing shallow seismic reflection data is the presence