Sedimentology and Stratigraphy of Mesozoic Rocks, Utah

University of Manitoba

February 15-25, 2023

Figure 1: The Crew poses near the western margin of the Cretaceous Mancos Shale; steeply dipping and folded Jurassic strata form the background.

Introduction

This trip involved a ten-day field trip to Utah where students had the opportunity to apply essential field-based mapping skills to world class outcrops of Mesozoic strata in the Colorado Plateau. Study areas included the Book Cliffs, the Navajo Sandstone at Arches National Park, the Moab Fault as well as many other locations. Exercises involved the mapping of sedimentary rocks and structures, field sketches, collecting measured sections and paleoflow data, physical correlation and, always, the architectural placement of the rocks into the structure of the depositional basin. The often-vertical sequences exposed by the topographic variations in Utah were a remarkable opportunity for the perennial flat-land students from the University of Manitoba to experience field-based geological exercises in rocks and settings they normally wouldn't be exposed to during their degrees.

The twelve attendees of the trip (Fig. 1) arrived in the study area on the evening of February 15 and included nine students, two professors, and one industry representative geologist. The twelve piled themselves and their gear into two Chrysler Pacifica's and began the drive to the town of Green River, ~292 km south of Salt Lake city. The first six days of the trip were spent in and around the Book Cliffs, where students familiarized themselves with sequence stratigraphy and the basic skills of conducting field work in this setting. Following this, the team mobilized further south to Moab, where they were fortunate to have the opportunity to visit Arches National Park, the Moab Fault and Canyonlands National Park. The final day of the trip was spent in the San Rafael desert, where students applied the skills they had learned throughout the course to a final mapping exercise focussed on the lower Cretaceous Cedar Mountain member.

Days 2-7: Book Cliffs

The first six days of field work were focussed on the Book Cliffs in Eastern Utah, which expose beautifully preserved architectural relations within the Cretaceous Blackhawk Formation, its individual members, the parasequences that comprise them, as well as the classic Panther Tongue Member. These

cliffs run for nearly 300 continuous kilometres, are up to 300m tall, and cut by numerous canyons that can add an important three-dimensional aspect to the rock exposures. The strata dip slightly towards the east and no major faults or folds affected them. Geologic interest was first drawn to the area for the extensive coal horizons in the northwest of the region, but in the 1980s the bulk of the scientific interest shifted to the shallow-marine deposits interfingering with the coals, which represent some of the best exposed examples in the world.

The Blackhawk Formation records a large-scale trend of basinward migration of the paleoshoreline in which many lower-order sequences are observed (Fig. 2). During the late Cretaceous,

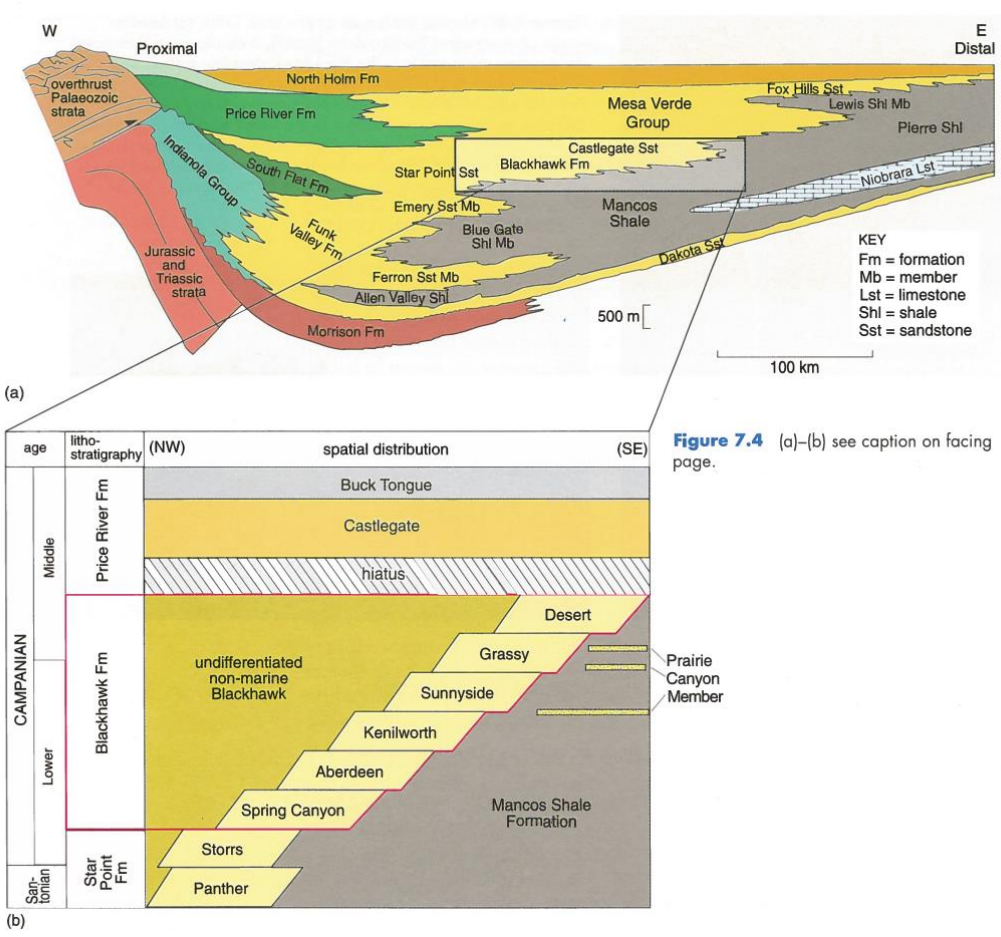

Figure 7.4 (a)–(b) see caption on facing page.

Figure 2: a) Cross-section of the Western Interior Basin in Utah showing the lithostratigraphy; and b) The lithostratigraphy of the Book Cliffs. After Coe (2003

the ongoing Sevier orogeny involved the subduction of the Farallon Plate along the western margin of the North American plate and resulted in a period of mountain building accompanied by the flooding of the interior of the continent. Variations in sediment supply related to the uplifting mountains and wet climate caused sporadic periods of delta progradation towards the east and into the flooded interior of North America. Consequently, the rocks of the Blackhawk Fm. transition from older and more distal assemblages in the east to younger and more proximal assemblages in the west. The first field days were spent in the northwest region of the Book Cliffs, where the upper strata of the Blackhawk Fm. record the furthest onshore assemblages, and progressively moved further east where the lower strata of the formation record increasingly more basinward depositional environments.

Daily exercises often involved stratigraphic mapping of sequences on drone-captured aerial images that allowed students to plot their field observations within the outcrop-scale architectural elements. The accurate identification of sedimentary structures was paramount in identifying the facies associations and making reasonable processes and environment interpretations. Sketches of the mapped rocks were encouraged to help students transfer key observations from their notebooks to maps and following each field exercise, “geo-wrap” sessions were carried out so that students and instructors could exchange their observations and ideas regarding the examined rocks.

Two of these exercises involved the correlation of outcrop observations with drill cores/logs that targeted the same rocks. Students had to correlate the rocks they had mapped in outcrop with the rocks and responses intersected in the drill core to develop larger-scale ideas on the architecture of the paleoshoreline. One day involved the logging of a core drilled by Shell in 1983 that targeted rocks of the Desert Member, which were mapped in a ~45m stratigraphic section the previous day. Industry representative Andrea Morgan, of Imperial Oil, provided insights from her experience at the Kearle mine in northern Alberta and discussed the reservoir potential of the individual horizons with the students (Fig. 3). The rocks of the Desert Member never represented a high priority exploration target for Shell,

however the excellence of the exposures allowed for the development of an accurate model and helped stress to students the significance of a working model when conducting resource exploration.

Figure 3: Andrea Morgan of Imperial Oil discusses the reservoir potential of the differing horizons of the Desert Member of the Blackhawk Fm at the John Wesley Powell Museum in Green River Utah.

In addition to the stratigraphic mapping, students participated in exercises designed to help garner an appreciation for the archaeological history and diverse rock assemblages of the Colorado Plateau. Petroglyphs were commonly observed in the visited canyons and at the Rochester Art panel students were tasked with sketching a portion of ~1300 year old petroglyphs and providing their own interpretation of what they think the artwork means. On the seventh day the crew stopped in to discuss an artificial geyser, which comprises a historic drill hole intersecting an artisanal well in Jurassic strata. The artisanal well here represents a horizon akin to some of the active critical metal exploration targets (Li, K, Rb) hosted in the unexposed Triassic rocks underlying those studied in the course, and a stimulating discussion on hydrogeology was had.

Figure 4: a) Native American rock art at the Rochester Art Panel near Emery, UT; b) students discuss and sketch a piece the rock art and interpret its significance.

Days 8-9: Moab Fault, Arches National Park, Canyonlands National Park

These two days were spent in the area around Moab, Utah, where the Moab Fault juxtaposes the Triassic and Pennsylvanian rocks to the west with the Jurassic rocks to the east. The fault was visited at a classic exposure along the interstate highway and students mapped various structures associated with the fault before stepping back to view the larger-scale picture of the structural geology here. The vans then drove through Arches National Park, where the members contemplated, discussed, and measured the features of the world-famous Navajo Sandstone in Arches National Park. Here, preferential weathering has carved out ancient dune-forms into the well-known and recognizable arches (Fig. 5a). The second day of the Moab detour began with a visit to the Triassic strata in Long Canyon, where the Chinle, Moenkopi and Wingate formations where students were tasked with developing a broad geologic history through a time-sensitive dissection of a highly complex outcrop. Of these three formations, the Chinle is particularly well-known for its preservation of petrified wood (e.g. Petrified Nation Forest, AZ), as well as the U and V mineralization that resulted from highly porous nature of the host sandstones and conglomerates. The second afternoon of the Moab tour was spent enjoying a view of the confluence between the Green and

Colorado Rivers from Canyonlands National Park (Fig. 5b) before driving back to Green River to prepare for the final mapping exercise.

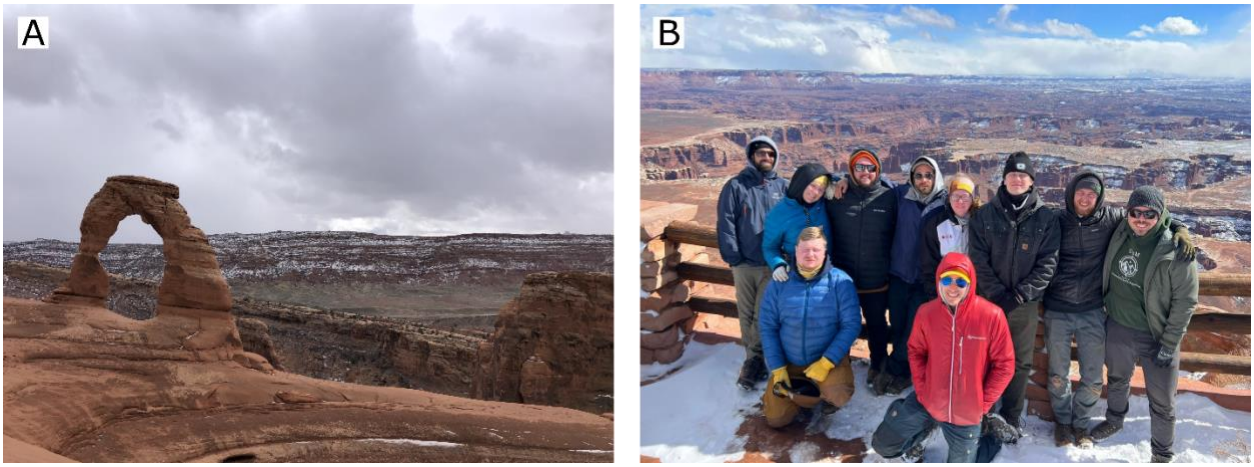

Figure 5: a) The Delicate Arch, of Arches National Park, UT, generated through the preferential weathering of the aeolian Navajo Sandstone; and b) The Crew poses in front of a viewpoint at Canyonlands National Park, UT

Day 10: Cedar Mountain Formation, San Rafael Desert

The field school culminated with a final mapping project in which the students applied the skills they had learned over the first nine days to a ~1km^2 map area containing many vertical and horizontal exposures of the lower Cretaceous Cedar Mountain Formation. Students were provided with a high-resolution hillshade digital elevation model and a drone-generated orthomosaic image to plot the collected section data, paleoflow measurements, bedding orientations and observed lithofacies spatially before evaluating the type of deposit and depositional environment represented in the rocks.

Summary

This ten-day field school involved roadside stops, canyon-road hikes, and tourist attraction visits that presented attendees with world-class exposures of Mesozoic Strata. The exercises of the course were tailored to help students strengthen their skills in lithostratigraphy, sedimentology and sequence stratigraphy but also helped build on many foundational aspects of field mapping, remote sensing, and

structural geology. The excellent exposures, amenable access, and thorough scientific review make this region an ideal field laboratory for the refinement and teaching of high-resolution sequence stratigraphy.

Acknowledgements

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