

Figure 1. Geologic map of the central Front Range (Tweto, 1979) showing field trip stops and the transition from out-of-the-basin thrusting to the north near Fort Collins to into-the-basin thrusting to the south near Boulder and Golden, CO.

Field Trip Description:

New lithosphere-scale seismic experiments in the northern Rockies show that lower-crustal detachment is the leading hypothesis for the formation of the enigmatic Laramide Rocky Mountains. This hypothesis was originally proposed in the Colorado Front Range on the basis of minor fault analyses and kinematic restorations. Come visit some of the key outcrops that generated this hypothesis and see how they can be linked with regional seismic data to give a unified thrust model for the Rockies. In addition, we will examine the resulting natural fracture systems that provide critical fluid conduits for tight reservoirs in successful resource plays (e.g., shale gas and oil) like the Niobrara Formation of the Denver Basin.

The plan is to keep it simple and active, both physically and mentally. For the first stops, we will visit Eldorado Canyon State Park, ½ way between Boulder and Golden, and enjoy its spectacular exposures, known world-wide for their climbing routes. At this set of stops, we will integrate everything from tiny minor faults to the Rocky Flats seismic line to build a regional tectonic framework that can be applied to basement-cored foreland arches world-wide. We will then apply this knowledge to resource plays in the Niobrara Formation at the classic 6 Mile Fold just north of Boulder.

These stops will involve moderate trail and off-trail walking to keep the blood flowing to our heads so we can puzzle out the Laramide Rockies. Please bring a range of clothing to protect from the weather, which can range from intensely sunny (extra water/hat/sunscreen/lip protection is essential) to blustery rainy (but probably not snow) conditions, all of which can change in an instant.

Stop 1: Structural Geology of Eldorado State Park

We will start by traversing the forelimb of the eastern Front Range on the Fowler Trail at Eldorado State Park, whose excellent exposures provide world-class climbing opportunities.

Stop 1a: Basement exposures of Proterozoic quartzites and schists.

We will take this opportunity to look at the basement rocks, view their discordance with the overlying Paleozoic Fountain Formation. We will discuss the Rocky Mountain enigma by proposing different hypotheses for the Laramide orogeny, asking the question of what differentiates this belt from simultaneous thin-skinned thrusting to the west, and discussing the new results from the Bighorn Project.

Stop 1b: Penn-Perm Fountain Formation exposures.

Here we will discuss the highly-cemented Fountain formation, whose induration is due to adularia (feldspar) cements which give puzzling ages of 135 and 94 Ma (Warnock, A.C. and van de Kamp, P.C., Hump-shaped $^{40}\text{Ar}/^{39}\text{Ar}$ age spectra in K-feldspar and evidence for Cretaceous authigenesis in the Fountain Formation near Eldorado Springs, Colorado: *Earth and Planetary Science Letters*, Volume 174, Issue 1-2, p. 99-111).

Stop 1c: Contact of Penn-Perm Fountain and Permian Lyons Formations.

This stop provides an excellent view of from the basement exposures to the west through the Boulder Flatirons that both bound the Denver Basin and the Laramide Rockies to the east. We will:

- 1) discuss the discordance of Paleozoic and Laramide structures, and their input into basement-involved foreland models,
- 2) interpret the seismic section through Rocky Flats to the south (see next page),
- 3) propose some structural models through the mountain front at Eldorado Springs, and
- 4) discuss the hypotheses for the discordance between the N-S to NNW-SSE mountain front structures and the NE-striking Marshall fault system to the east.

Stop 1d: After returning to the vans and shuttling east to the first parking area, we will cross the creek on the Streamside Trail, looking for minor faults to test our structural hypotheses.

Stop 2: A traverse of Six Mile Fold north of Boulder, CO

This stop will traverse an out-of-the basin structure in the Niobrara Formation. The Niobrara Formation is a Cretaceous sequence of limestones, cherts and marls that contain both oil-bearing marls and effectively-fractured marls. This combination makes it an economic resource play, and current production is driving an oil boom in NE Colorado, and elsewhere in the eastern Rockies. Natural fractures are commonly cited as the factor that makes or breaks individual wells

We will first walk out the fold in the basal Fort Hayes Limestone, mapping it (using the photo on the last page) and using its contact relationships to propose a sequential Laramide fold model. Then we will examine the minor structures to test our models while walking into the sequence of marls and cherts that provide the major sources and reservoirs for this resource play.

We will conclude by viewing an intriguing exposure with reactivated faults and discuss some of the societal benefits and challenges of resource plays for the world.

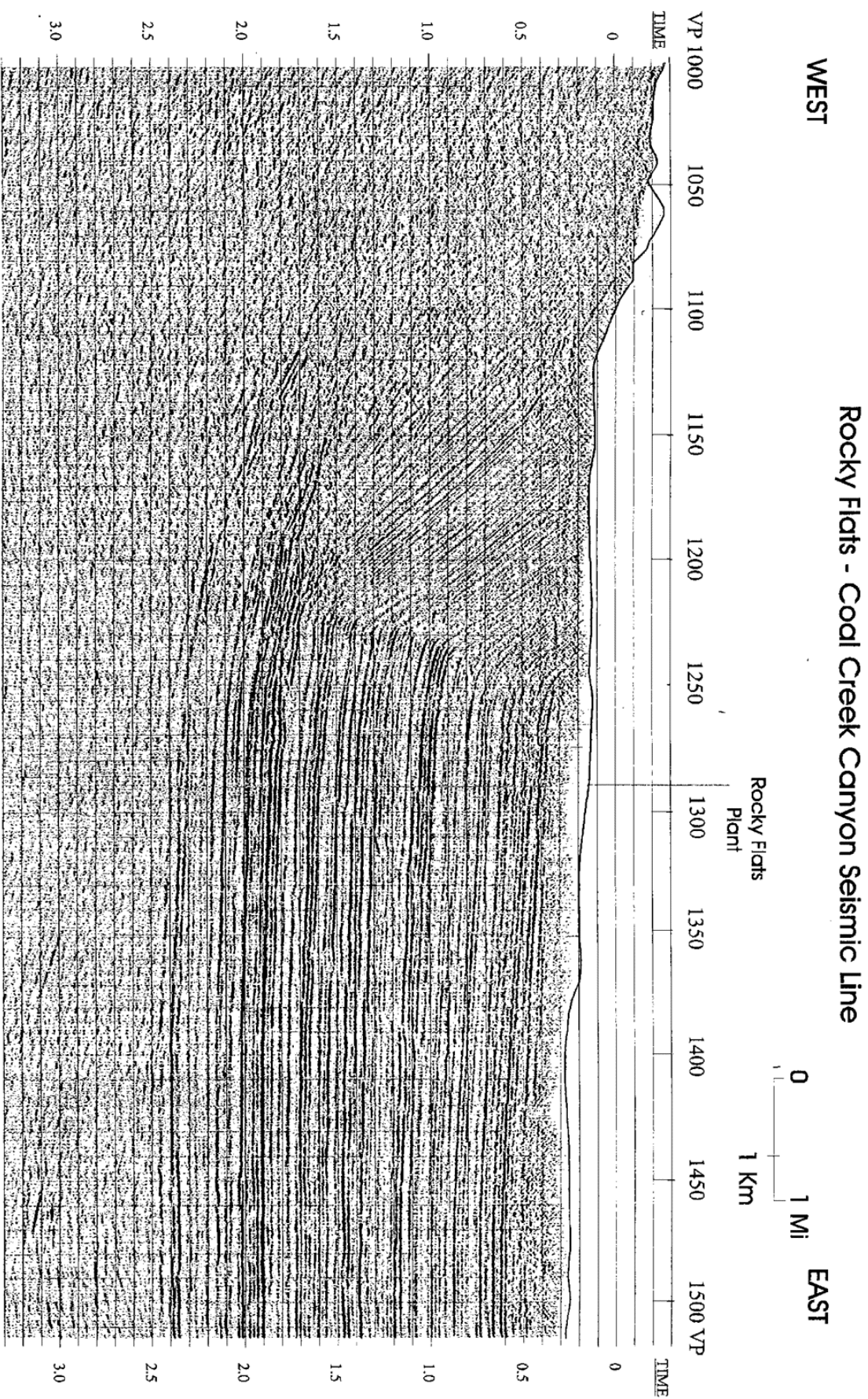
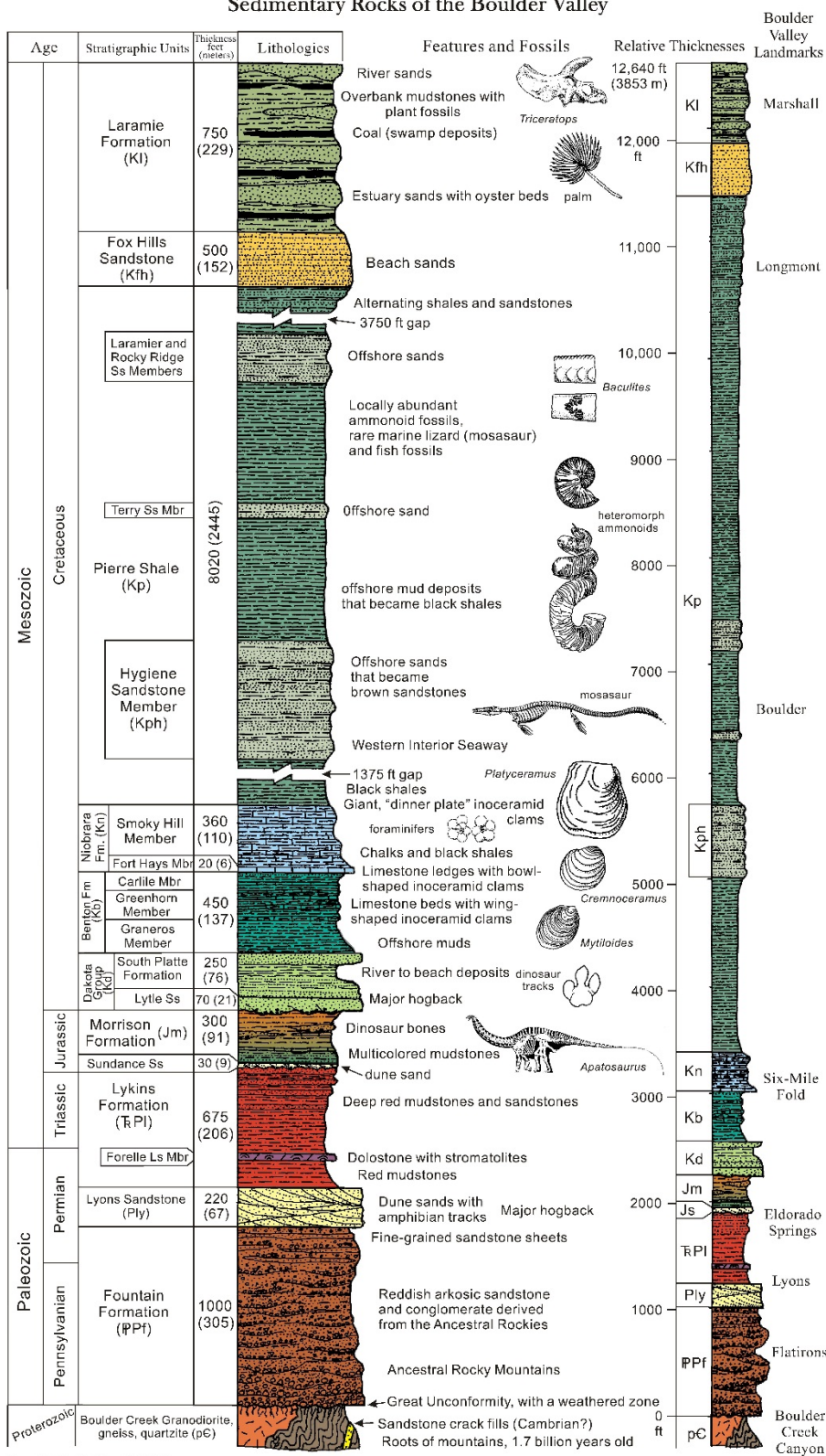


FIGURE 9. Uninterpreted, DMO Time migrated seismic section from Coal Creek Canyon (DOE, 1993) through Rocky Flats. See text and Figure 10 for discussion and interpretation of tectonic features shown on this section.



Sedimentary Rocks of the Boulder Valley



Compiled by E. Evanoff, 2001