PS Pre-Existing Structures and Initiation of an Oblique Rift: the Cañones Fault Zone in North-Central New Mexico*

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Abstract

The earliest fault in an intracontinental rift tells us a lot: when the rifting initiated, where the weak zone in the crust was, how the upper plate moved relative to the lower plate, etc. Here we present our field mapping results and discuss its implications on the tectonic model of the initiation of an oblique rift. The Cañones fault zone in north-central New Mexico is a boundary between the Colorado Plateau to the west and the Rio Grande Rift to the east. Offsetting a 20-Ma basaltic dike and the Oligocene Ritito Conglomerate, it is one of the oldest faults in the western flank of Española Basin, Rio Grande Rift. It consists of a master fault, the Cañones Fault (CF), a transfer fault, the Las Minas Fault (LMF), and a family of synthetic and antithetic faults. The South CF is a SE-dipping high-angle normal fault, striking ~040°; the North CF, however, dips NW while strikes NE, too. The South and North CF have a similar arcuate trace while the near E-W-striking LMF connects them in the middle. Detailed mapping and fault kinematic studies from the slickenlines on fault surfaces reveal that the relative movement orientations on the Cañones Fault range 070°~130°, and average 100°, and thus characterized an oblique rift. The LMF is a left-lateral strike-slip fault, based on the sub-horizontal slickenlines, and hence accommodated the movement on the hanging-wall blocks of both South and North CF. A noteworthy phenomenon along the Cañones fault zone is that both South and North CF juxtapose a monocline in the hanging-wall block upon the sub-horizontal footwall strata. The monoclines are shortening structures, probably formed during the Laramide Orogeny. A series of right-stepping, en echelon thrusts and uplifts are preserved adjacent to our study area. Along the South CF, a monocline locates to the east of the fault and is west vergent; along the North CF, in contrast, the other monocline locates to the west of the fault and is east vergent. The polarity switch of the monoclines is consistent spatially with the dip direction change of the Cañones Fault. We also observed three reverse faults and two reactivated normal faults on one outcrop. Our model suggests that after the Laramide shortening weakened the core of monoclines, the following Rio Grande Rift extension initiated obliquely along these weak zones. Therefore, the pre-existing shortening structures strongly influenced the structure of the rift-bounding faults when the extension initiated.

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Introduction

Understanding how and why strain is localized onto a border fault is key to a detailed structural and kinematic model of a rift basin. Here we present our field mapping results, in order to discuss factors that control the evolution of a border fault, the Cañones fault, in north-central New Mexico. It marks a boundary between the Colorado Plateau to the west and the Rio Grande Rift to the east.

Based on detailed mapping and map reading, we identify different patterns of the spatial relations of folding and faulting along and away from the Cañones Fault. We propose that during its formation of a border fault, strain localizes onto the Cañones fault because of the following factors:

(1) Pre-existing weaknesses in the shallow crust due to faulting and folding;
(2) Favored juxtaposition of monocline and normal faults;
(3) Preferential orientations of two sets of the juxtaposition for the development of an accommodation zone that increases the total displacement within the Cañones fault system.

Fig.1 **Tectonic map of the north-central New Mexico.**
The blue, dashed loop shows the extent of the Abiquiu Embayment.

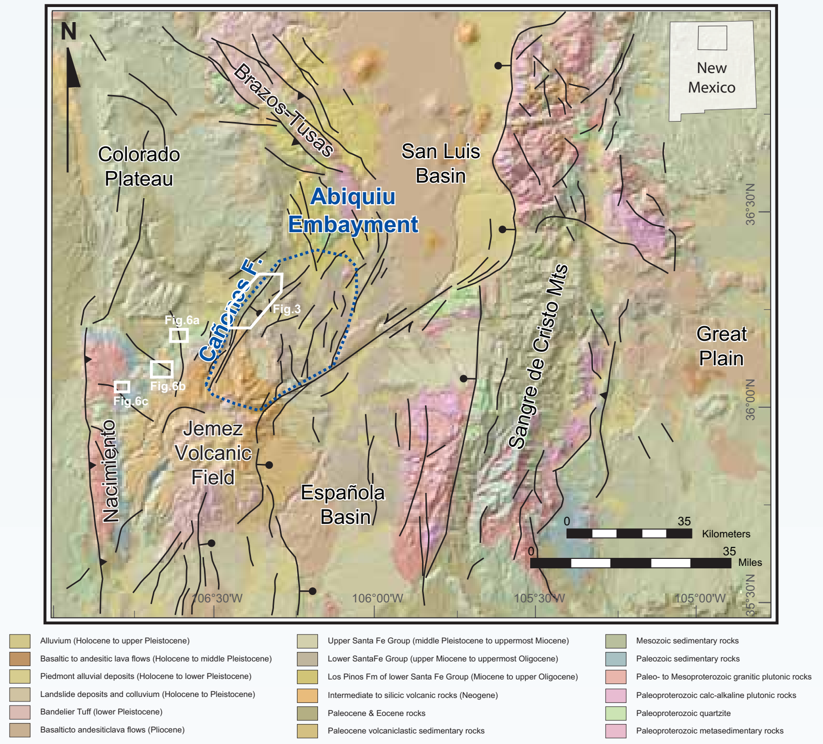


Fig.2 Gravity inversion map showing the elevation of the base of the Cenozoic basin fills. The Abiquiu Embayment is a shallow basin with a few 100s m thick, while the San Luis Basin and the Española Basin are asymmetric and deep, forming the axial basin of the Rio Grande rift system.

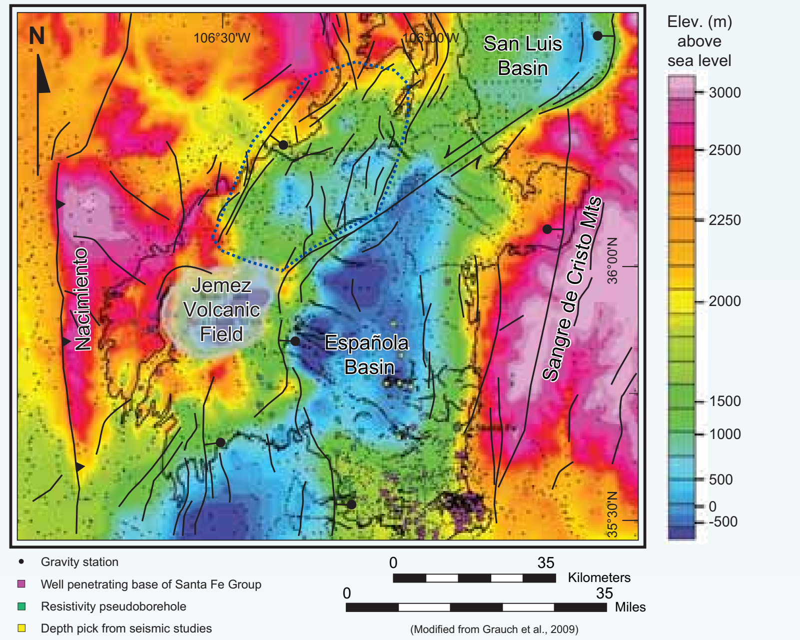


Fig.3 **Geologic map of the Cañones fault system.**
Cenozoic basin fills (Ritito and Abiquiu Formations) characterize the western border of the early Rio Grande rift. The southern portion of the Cañones fault is SE dipping, while the northern portion is NW dipping. An accommodation zone connects both portions of the Cañones fault.

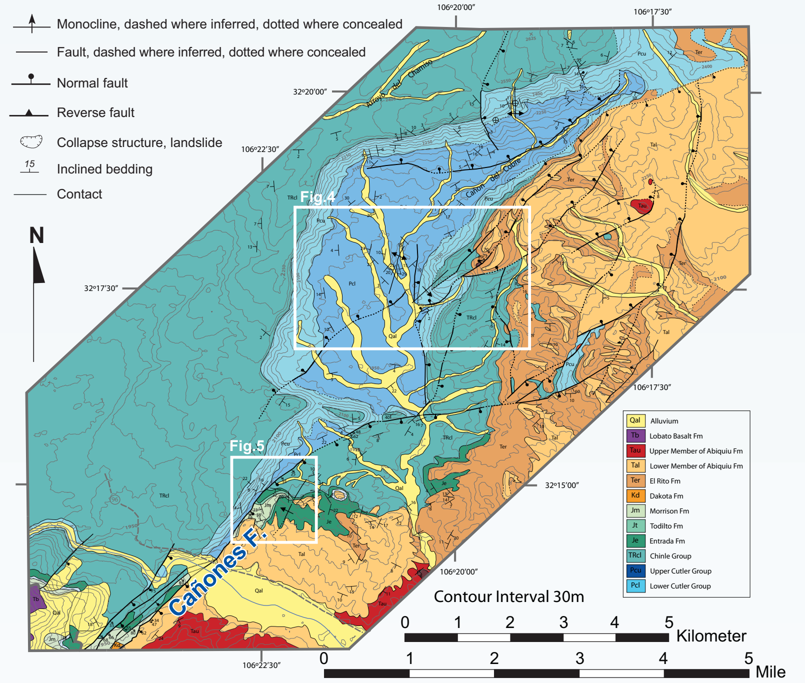
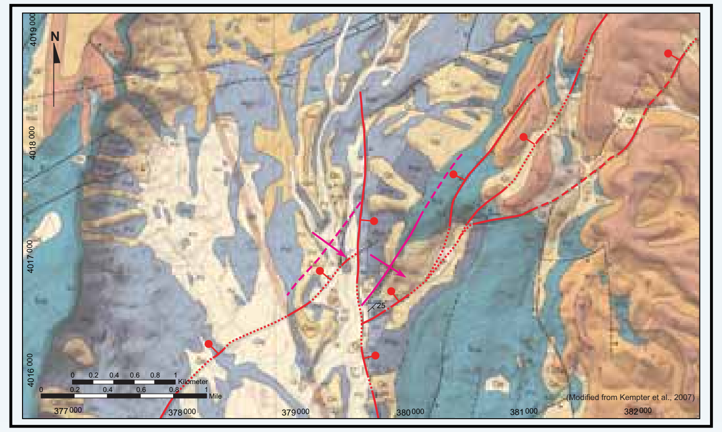


Fig.4 **Geologic Map of the Cañones Fault in the northern part (Arroyo del Cobre area)**
Below it is a field picture showing a NW-dipping normal fault and the SE-vergent monocline in the hanging wall of the normal fault



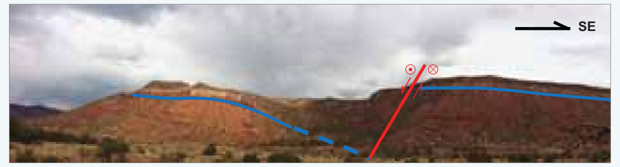
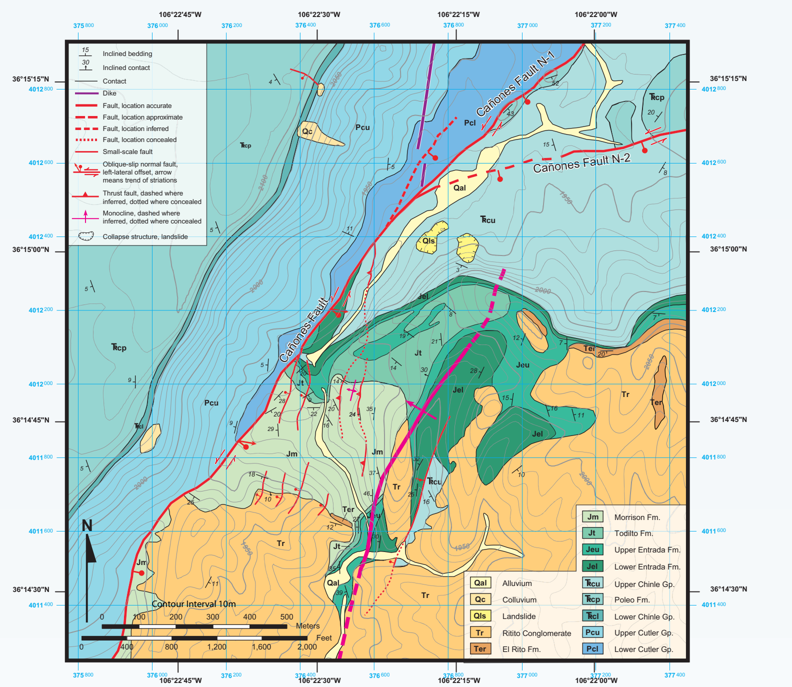
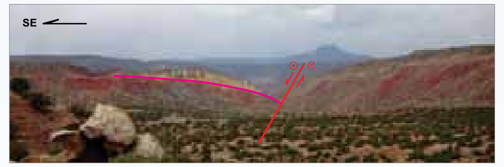
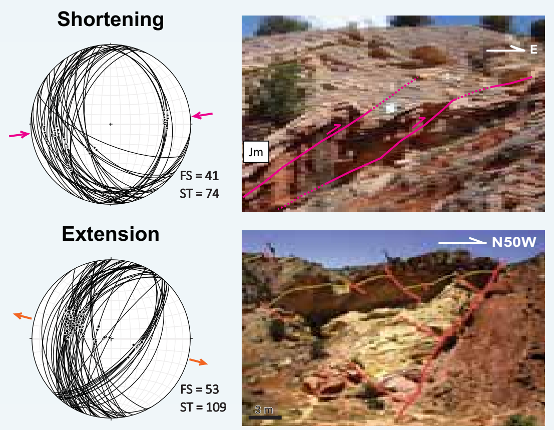


Fig.5 **Geologic Map of the Cañones Fault at the northern end of the southern portion (Red Wash Canyon area)**



This field picture shows a SE-dipping normal fault and a NW-vergent monocline in the hanging wall of the normal fault.



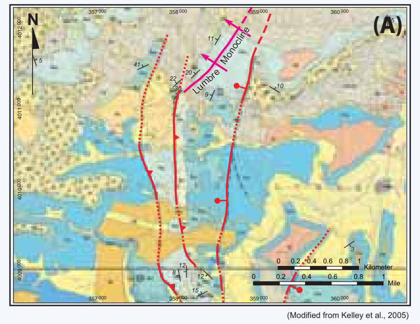


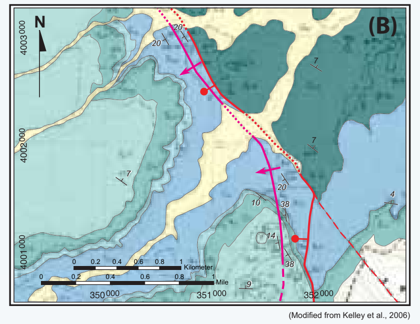
Mesozoic rocks record the E-W shortening and the NNW-SEE extension.

Note that the obliquity of the rifting from the shortening direction is small (20°), which is preferential for fault reactivation.

Fig.6 **Geologic maps of three areas to the west of the Cañones Fault.**
Here preserve diffrent patterns of the spatial relationships between folds and faults. (A). The Lumbre monocline and faults in Youngsville area. (B). The Mesa Montosa monocline and fault in Arroyo Del Agua Mesa area. (C). The San Pedro monoclines and fault in Jarosa area.

Note the vergence of folds and the dip direction of normal faults, which are in the same sense, differing from the Cañones Fault where they are opposite.





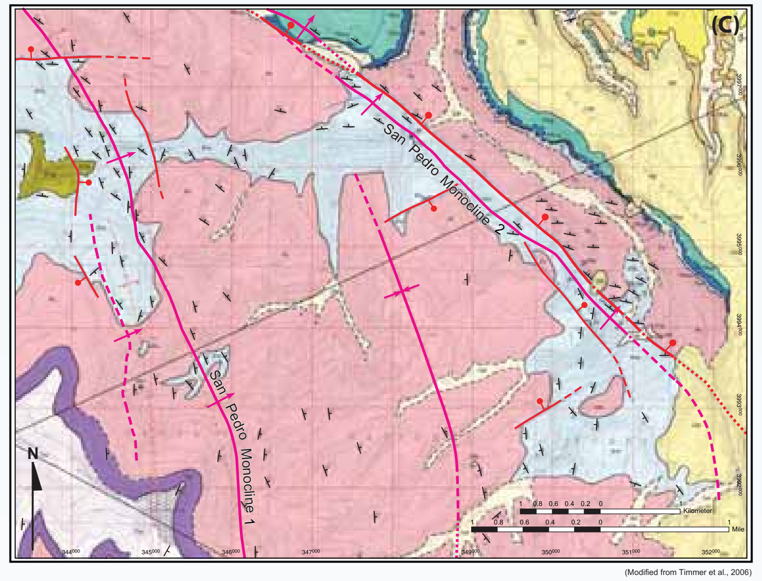
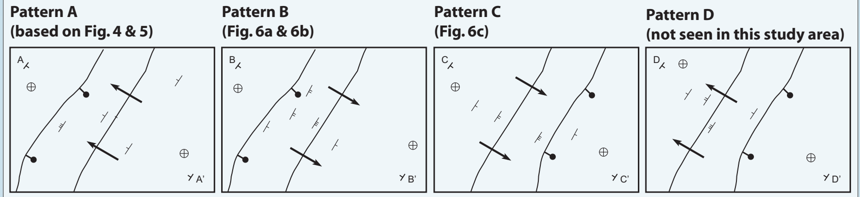
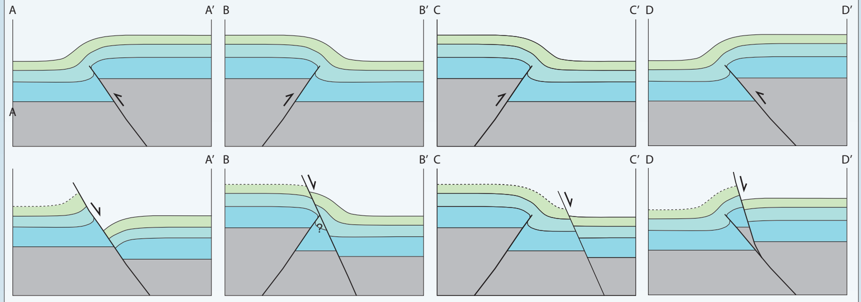


Fig.7 **Four patterns of the juxtaposition of monocline and normal fault.**
This classification is based on (1) the vergence of the monocline and the dip direction of the normal fault, and (2) whether the monocline is present in the hanging wall or footwall of the normal fault.



We propose to use reactivation model to explain the structural evolution based on the fact that Laramide shortening is followed by the Rio Grande extension.



Alternative model and comments:
For (A): Rollover structure, which will project a detachment at a unrealistically shallow depth and fails to explain thrusts seen in the monocline in the Red Wash Canyon.
For (B) & (C): Extensional fault-propagation fold (drag-fold) model, which fails to explain the thrusts near the monocline in Fig. 6A; also, some monoclines (not shown here) crop out without the accompany of a normal fault.

Discussion & Conclusion

Tectonic evolution of the Cañones Fault, the Abiquiu Embayment, and their adjacent area during late Cretaceous to Miocene:

1. The Laramide Orogeny creates basement-involved thrusts, uplifts, and sparsely-distributed monoclines.

2. Initiation of the Rio Grande rifting reactivates many pre-existing faults to extension, and also generates new normal faults.

3. Two sets of the juxtapostion of a monocline and a normal fault happen to lie on a line whose trend is sub-orthogonal to the extensional direction, i.e. low obliquity during extension from pre-existing structures.

4. An accommodation zone developes between the northern and southern portions of the Cañones Fault, and hence the fault system keeps growing longer and accommodate more extension strain. Finally it forms the border fault of the Rio Grande rift in north-central New Mexico.

Acknowledgements

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