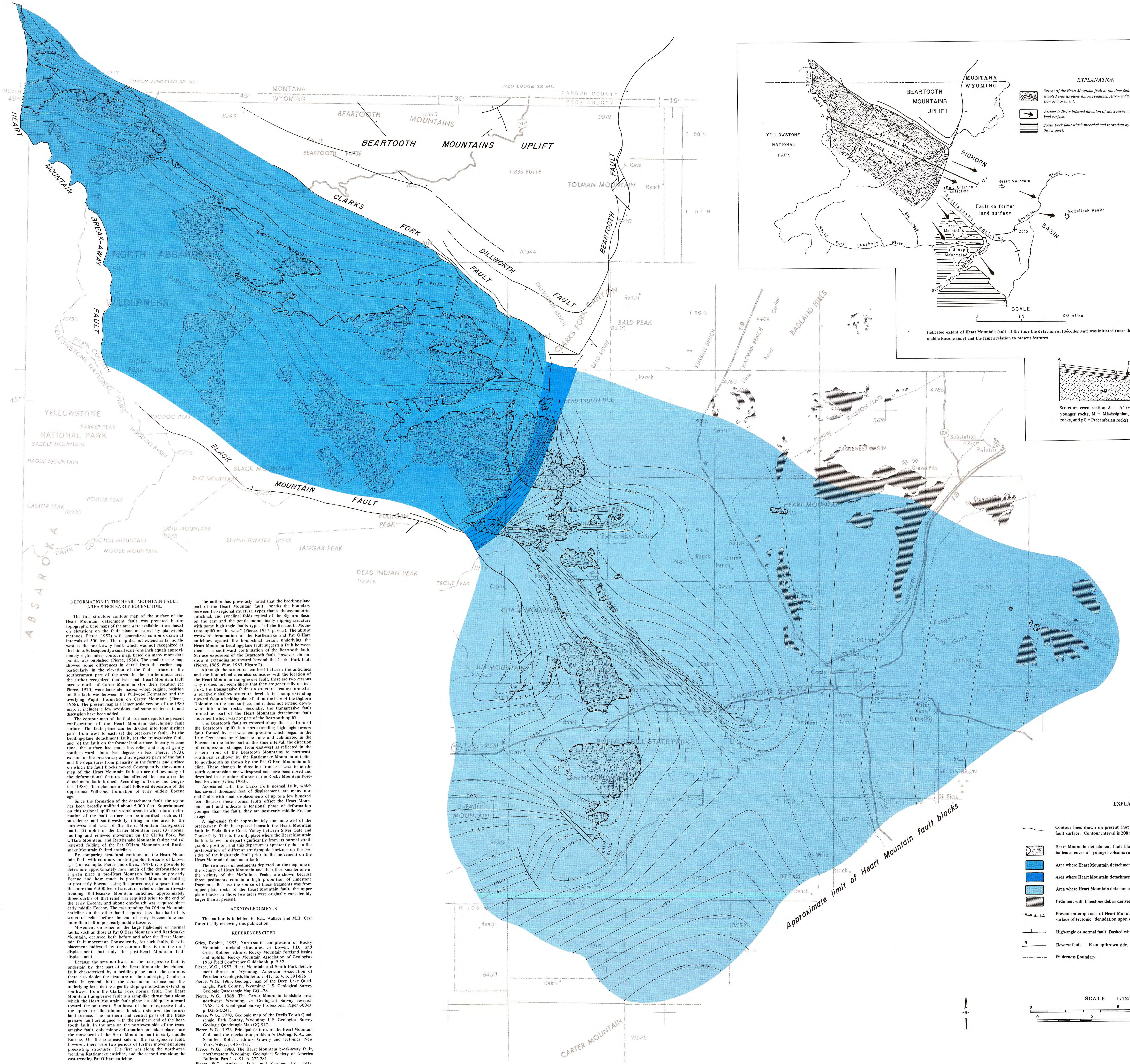
THE GEOLOGICAL SURVEY OF WYOMING
Gary B. Glass, State Geologist



Indicated extent of Heart Mountain fault at the time the detachment (décollement) was initiated (near the close of early middle Eocene time) and the fault's relation to present features.

Structure cross section A – A' (vertical exaggeration 2X; P = Pennsylvanian and younger rocks, M = Mississippian, Devonian, and Ordovician rocks, C = Cambrian rocks, and pЄ = Precambrian rocks).

DEFORMATION IN THE HEART MOUNTAIN FAULT AREA SINCE EARLY EOCENE TIME

The first structure contour map of the surface of the Heart Mountain detachment fault was prepared before topographic base maps of the area were available; it was based on elevations on the fault plane measured by plane-table methods (Pierce, 1957) with generalized contours drawn at intervals of 500 feet. The map did not extend as far northwest as the break-away fault, which was not recognized at that time. Subsequently a small scale (one inch equals approximately eight miles) contour map, based on many more data points, was published (Pierce, 1980). The smaller scale map showed some differences in detail from the earlier map, particularly in the elevation of the fault surface in the southernmost part of the area. In the southernmost area, the author recognized that two small Heart Mountain fault masses north of Carter Mountain (for their location see Pierce, 1970) were landslide masses whose original position on the fault was between the Willwood Formation and the overlying Wapiti Formation on Carter Mountain (Pierce, 1968). The present map is a larger scale version of the 1980 map; it includes a few revisions, and some related data and discussion have been added.

The contour map of the fault surface depicts the present configuration of the Heart Mountain detachment fault surface. The fault plane can be divided into four distinct parts from west to east: (a) the break-away fault, (b) the bedding-plane detachment fault, (c) the transgressive fault, and (d) the fault on the former land surface. In early Eocene time, the surface had much less relief and sloped gently southeastward about two degrees or less (Pierce, 1973), except for the break-away and transgressive parts of the fault and the departures from planarity in the former land surface on which the fault blocks moved. Consequently, the contour map of the Heart Mountain fault surface defines many of the deformational features that affected the area after the detachment fault formed. According to Torres and Gingerich (1983), the detachment fault followed deposition of the uppermost Willwood Formation of early middle Eocene age.

Since the formation of the detachment fault, the region has been broadly uplifted about 5,000 feet. Superimposed on this regional uplift are several areas in which local deformation of the fault surface can be identified, such as (1) subsidence and southwesterly tilting in the area to the northwest and west of the Heart Mountain transgressive fault; (2) uplift in the Carter Mountain area; (3) normal faulting and renewed movement on the Clarks Fork, Pat O'Hara Mountain, and Rattlesnake Mountain faults; and (4) renewed folding of the Pat O'Hara Mountain and Rattlesnake Mountain faulted anticlines.

By comparing structural contours on the Heart Mountain fault with contours on stratigraphic horizons of known age (for example, Pierce and others, 1947), it is possible to determine approximately how much of the deformation at a given place is pre-Heart Mountain faulting or pre-early Eocene and how much is post-Heart Mountain faulting or post-early Eocene. Using this procedure, it appears that of the more than 6,500 feet of structural relief on the northwest-trending Rattlesnake Mountain anticline, approximately three-fourths of that relief was acquired prior to the end of the early Eocene, and about one-fourth was acquired since early middle Eocene. The east-trending Pat O'Hara Mountain anticline on the other hand acquired less than half of its structural relief before the end of early Eocene time and more than half in post-early middle Eocene.

Movement on some of the large high-angle or normal faults, such as those at Pat O'Hara Mountain and Rattlesnake Mountain, occurred both before and after the Heart Mountain fault movement. Consequently, for such faults, the displacement indicated by the contour lines is not the total displacement, but only the post-Heart Mountain fault displacement.

Because the area northwest of the transgressive fault is underlain by that part of the Heart Mountain detachment fault characterized by a bedding-plane fault, the contours there also depict the structure of the underlying Cambrian beds. In general, both the detachment surface and the underlying beds define a gently sloping monocline extending southwest from the Clarks Fork normal fault. The Heart Mountain transgressive fault is a ramp-like thrust fault along which the Heart Mountain fault plane cut obliquely upward toward the southeast. Southeast of the transgressive fault, the upper, or allochthonous blocks, rode over the former land surface. The northern and central parts of the transgressive fault are aligned with the southern end of the Beartooth fault. In the area on the northwest side of the transgressive fault, only minor deformation has taken place since the movement of the Heart Mountain fault in early middle Eocene. On the southeast side of the transgressive fault, however, there were two periods of further movement along preexisting structures. The first was along the northwest-trending Rattlesnake anticline, and the second was along the east-trending Pat O'Hara anticline.

The author has previously noted that the bedding-plane part of the Heart Mountain fault, "marks the boundary between two regional structural types, that is, the asymmetric, anticlinal, and synclinal folds typical of the Bighorn Basin on the east and the gentle monoclinally dipping structure with some high-angle faults typical of the Beartooth Mountains uplift on the west" (Pierce, 1957, p. 615). The abrupt westward termination of the Rattlesnake and Pat O'Hara anticlines against the homoclinal terrain underlying the Heart Mountain bedding-plane fault suggests a fault between them – a southward continuation of the Beartooth fault. Surface exposures of the Beartooth fault, however, do not show it extending southward beyond the Clarks Fork fault (Pierce, 1965; Wise, 1983, Figure 2).

Although the structural contrast between the anticlines and the homoclinal area also coincides with the location of the Heart Mountain transgressive fault, there are two reasons why it does not seem likely that they are genetically related. First, the transgressive fault is a structural feature formed at a relatively shallow structural level. It is a ramp extending upward from a bedding-plane fault at the base of the Bighorn Dolomite to the land surface, and it does not extend downward into older rocks. Secondly, the transgressive fault formed as part of the Heart Mountain detachment fault movement which was not part of the Beartooth uplift.

The Beartooth fault as exposed along the east front of the Beartooth uplift is a north-trending high-angle reverse fault formed by east-west compression which began in the Late Cretaceous or Paleocene time and culminated in the Eocene. In the latter part of this time interval, the direction of compression changed from east-west as reflected in the eastern front of the Beartooth Mountains to northeast-southwest as shown by the Rattlesnake Mountain anticline to north-south as shown by the Pat O'Hara Mountain anticline. These changes in direction from east-west to north-south compression are widespread and have been noted and described in a number of areas in the Rocky Mountain Foreland Province (Gries, 1983).

Associated with the Clarks Fork normal fault, which has several thousand feet of displacement, are many normal faults with small displacements of up to a few hundred feet. Because these normal faults offset the Heart Mountain fault and indicate a tensional phase of deformation younger than the fault, they are post-early middle Eocene in age.

A high-angle fault approximately one mile east of the break-away fault is exposed beneath the Heart Mountain fault in Soda Butte Creek Valley between Silver Gate and Cooke City. This is the only place where the Heart Mountain fault is known to depart significantly from its normal stratigraphic position, and this departure is apparently due to the juxtaposition of different stratigraphic horizons on the two sides of the high-angle fault prior to the movement on the Heart Mountain detachment fault.

The two areas of pediments depicted on the map, one in the vicinity of Heart Mountain and the other, smaller one in the vicinity of the McCulloch Peaks, are shown because those pediments contain a high proportion of limestone fragments. Because the source of those fragments was from upper plate rocks of the Heart Mountain fault, the upper plate blocks in those two areas were originally considerably larger than at present.

ACKNOWLEDGMENTS

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EXPLANATION

- Contour lines drawn on present (not original) configuration of the Heart Mountain detachment fault surface. Contour interval is 200 feet. Datum is mean sea level.
- Heart Mountain detachment fault block. Faults within block not shown. Unpatterned area indicates cover of younger volcanic rock.
- Area where Heart Mountain detachment is a bedding-plane fault.
- Area where Heart Mountain detachment is a transgressive fault.
- Area where Heart Mountain detachment is on former land surface.
- Pediment with limestone debris derived from Heart Mountain fault block.
- Present outcrop trace of Heart Mountain fault. Sawteeth on side of upper plate; hachures on surface of tectonic denudation upon which volcanic rocks were deposited.
- High-angle or normal fault. Dashed where inferred. Bar and ball on downthrown side.
- Reverse fault. R on upthrown side.
- Wilderness Boundary

SCALE 1:125,000

0 5 10 miles

0 5 10 15 kilometers

Cartography by Betty S. Wills

MAP SHOWING PRESENT CONFIGURATION OF HEART MOUNTAIN FAULT AND RELATED FEATURES, WYOMING AND MONTANA

by

William G. Pierce

1985