ignored. Extremely wide rings may be noted. Ring widths are judged in relation to nearby rings, thus removing the effect of the tendency of tree rings to decrease in width as trees age.

Missing rings occur when portions of a tree stem show no discernible growth during years of severe environmental stress. The subjective judgement exercised to determine where missing rings should occur in a skeleton plot casts doubt on the bristlecone pine chronology.[3]

Ring widths can be accurately measured under magnification with machines designed for this purpose. Hamilton[4] has described an instrument which can be built in the average university shop. These measurements can then be graphed for visual or statistical comparisons. Visual comparisons, again, inject a subjective element reducing the reliability of assumed chronologies.

Correlation coefficients calculated between all possible matches for two series of ring indices tend to be randomly distributed around "zero", except at the match point where a highly significant positive correlation may be obtained.

Attention to Some Problems

Baillie and Pilcher[5] recommended the transformation of ring-width data for this analysis by (1) expressing the ring width as a percentage of the mean of the five ring widths of which it is the central value, and (2) normalizing by taking the log to the base *e* of the percentage figures. They emphasized, however, that this analysis is valid only where no missing or double rings occur. Again, the bristlecone pine chronology, with many missing rings[6], would not be useful in this less subjective statistical approach.

Also, A. C. Barefoot[7], a professor at North Carolina State University, working with oaks in England found correlation coefficients of .99 between ring-width series known to be wrong while those known to be correct were .90. I conducted a preliminary study with oaks in West Virginia and noted the same tendency. The probability of this type error can be calculated of course, and increases with poorer correlations.

Double, multiple, or false rings may occur when suitable growth periods are interrupted by droughts, defoliation by insects or late frosts or other unusual conditions.[8] False rings appear to occur more frequently in *Pinus* as one moves south, presenting a serious problem in tree-ring studies in Mexico. The unusual climate which must have followed the deluge may have caused the formation of many false rings in the older bristlecone pines in what is now the southwestern United States, increasing their apparent age.

Conclusion

Dendrochronology, as all dating schemes, is based upon certain assumptions and subjective procedures, and creationists need not be dismayed by the long chronologies claimed to have been established. This field should be a fruitful area for more study by those accepting the young-earth model.

References

[1]Sorensen, H. C. 1976. Bristlecone pines and tree-ring dating: a critique, *Creation Research Society Quarterly* 13(1):5-6.

[2]Avery, T. E. 1975. Natural Resources Measurements. McGraw-Hill Book Co., New York, chapter 15.

[3]Sorensen, H. C., *Op. cit.*

[4]Hamilton, J. R. 1963. A dual-linear micrometer, *Forest Products Journal* 13:70.

[5]Baillie, M. G. L., and J. R. Pilcher. 1973. A simple crossdating program for tree-ring research, *Tree Ring Bulletin* 33:7-13.

[6]Sorensen, H. C. *Op. cit.*

[7]Barefoot, A. C. Personal communications at Third Annual Hardwood Symposium, Cashiers, NC, May 1, 1975.

[8]Brown, H. P., A. J. Panshin, and C. C. Forsaith. 1949. Textbook of Wood Technology. Vol. I. McGraw-Hill Book Co., New York, pp. 39-40.

HEART MOUNTAIN REVISITED

CLIFFORD L. BURDICK*

At the Heart Mountain formation, Wyoming, and at other places, strata are in the wrong order, according to the uniformitarian view, supposedly older rocks being on top of supposedly younger ones. Such formations have been ascribed to the overthrusting of older rock over the younger. However, at many of these formations, including Heart Mountain, there is no physical evidence for such sliding; nor is there any proof that such motion is mechanically possible. Some recent investigation has again failed to provide any evidence that Heart Mountain was overthrusted; but there is evidence that a normal vertical fault was involved.

Introduction

Structural geologists have long recognized low-angle faults or thrust faults as one of the effects of tectonic activity in the crust of the earth, along with normal faults and strike-slip faults.

Regardless of the type of fault, where there has been differential movement along a fault plane, there is bound to be a grinding action, as is the case with the plates of any mill. Contact metamorphism may be one effect, especially where heat and pressure are involved. Other physical criteria resulting are:

1) Ground up rock, or mylonite, a layer between the moving blocks.

2) Tectonic breccia, or large fragments of broken, angular rock.

3) Slickensides, or fluting or grooves where the rough or angular projections have grooved the other plate.

Some early paleontologists were not well versed in structural geology and were inclined to ignore structure. They believed that the fossil evidence was so

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overwhelming that it was a waste of time to check the physical criteria; and, as one paleontologist put it:

> It may even be said that in any case where there appears to be a clear and decisive discordance between the physical and the paleontological evidence as to the age of a given series of beds, it is the former that is to be distrusted rather than the latter.[1]

What a strange infatuation with deductive reasoning as against inductive reasoning—pitting an unprovable hypothesis against field evidence! Sir Archibald Geikie,[2] one time director of the Geological Survey of Great Britian, described the so called overthrusts of the Alps:

"The strata could scarcely be supposed to have been really inverted, save for the evidence as to their true order of succession supplied by their included fossils."

It is with this thought in mind that so-called overthrusts or low-angle faults should be examined. It is not maintained that all such structures are misnamed; but one should be on guard to examine all cases critically, to see if the physical evidence, mylonite, tectonic breccia, and slickensides along the thrust contact accompany the fossil evidence.

It is not denied that some actual overthrusts have all the physical criteria of thrusts—such structures do exist.

The Heart Mountain Thrust

I have spent some time in the field in northwest Wyoming examining the so called Heart Mountain Thrust, a few miles north of Cody, Wyoming. This is an isolated capping of Madison (Mississippian) limestone (See Figure 1).

William G. Pierce[3] of the U. S. Geological Survey has written up the Cathedral Cliffs formation. He imagined igneous rocks moving on the Madison limestone as it was supposedly thrust southeastward by the Heart Mountain detachment fault which scattered isolated blocks of Madison limestone for many miles in northwest Wyoming. Pierce has also written concerning the Heart Mountain thrust.

This thrust movement is supposed to have taken place in Eocene time, along a nearly horizontal surface; whether as a compressional thrust or as a gravitational slide is not clear, although the mechanics of either is still more obscure. Geological maps show the Heart Mountain Madison limestone resting on Tertiary limestone or dolomite. In other blocks it rests on Cambrian Grove Creek formation, the intervening Devonian, Silurian, and Ordovician formations being missing.

If the missing formations are the only criteria for calling Heart Mountain a thrust, then by the same token the Mississippian Redwall formation in the Grand Canyon could be called a thrust, though I have never heard it so called. In the case of the Grand Canyon, in most places along the trails the Redwall rests directly on the Cambrian, the intervening Devonian, Silurian, and Ordovician being missing.

Some geologists interpret the Heart Mountain structure with several missing formations as a case of gravitational gliding, where the Mississippian formations erased the intervening Devonian, Silurian and Ordovician formations, and left the Madison resting directly on the Cambrian or Tertiary as the case may be. But just as at the Grand Canyon that explanation just does not fit the case; for not a sliver of the intervening formations remain. The contact seems conformable; that is, a normal sedimentary contact in the case of Heart Mountain or the Grand Canyon.

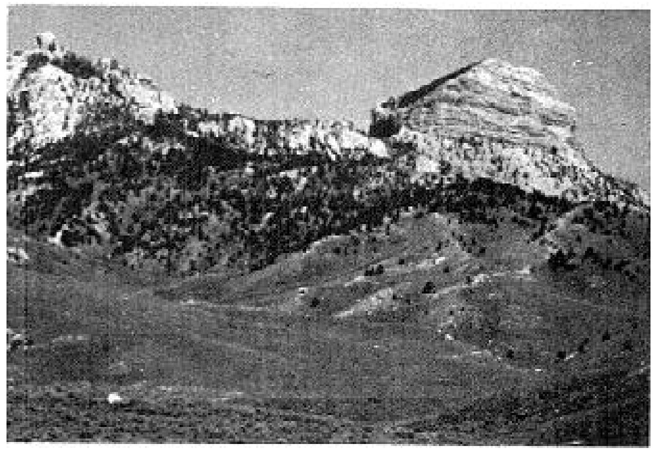

Figure 1. Heart Mountain, a few miles north of Cody, Wyoming.

Window Rock, Arizona

In the Window Rock area of Eastern Arizona, there is a still more anomalous contact; this time the Permian Supai formation rests on the Older Precambrian, Archeozoic quartzite. The standard explanation is that for a billion years or so the area was just enough above water to avoid both deposition and erosion.

This would appear to be a far-fetched explanation at best; for Twenhofel[4] has said that the crust of the earth is never really at rest for very long. At Glen Rose, Texas along the Paluxy river about 20 years ago I photographed some perfect dinosaur tracks. When I attempted to rephotograph the same tracks, they had been eroded away.

Difficulties with the Motion of Thrusts

A major objection to both the thrust and gravitational gliding theories is that the thrust contact is practically level; also there is no down grade to explain the gliding, nor rock competency sufficient to allow pushing these blocks over long distances without fracturing and making breccia and rubble. Furthermore, no source has been found from where such a thrust could have started. Authorities readily admit such deficiencies in the whole thrust hypothesis. They seem unable to visualize that the defect is in the fossil sequence dogma rather than in rock structure.

Isolated blocks of Mississippian Madison limestone are scattered over many miles of northwest Wyoming. According to Pierce[5], "Were it not for the absence of some formations the presence of a fault might not be, recognized."

This is tantamount to an admission that a principal basis of designating this structure as a thrust is the absence of intervening formations. If that is a valid argument, then most of Arizona is a giant thrust, for in

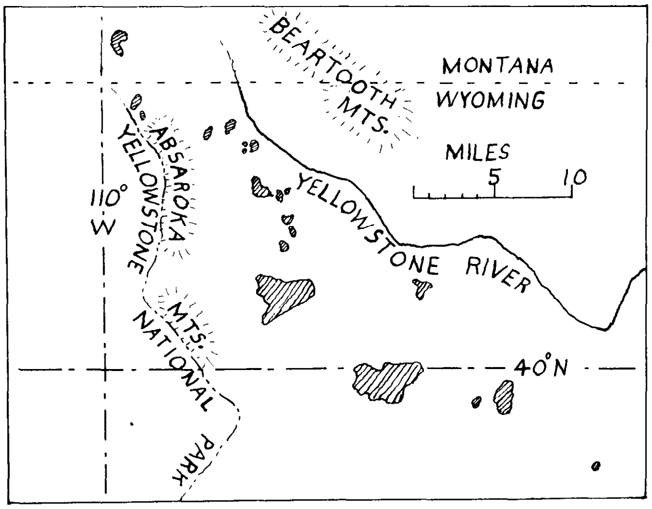

Figure 2. This is a map of the country in the vicinity of Heart Mountain. The lines marked "40°N" and "110°W" indicate latitude and longitude; the other broken lines are state boundaries, or the boundary of Yellowstone Park. The various blocks into which the alleged thrust is broken are shown cross-hatched.

most of that state the Ordovician and Silurian rock formations are missing.

This is a monument to the power of "*a priori*" reasoning; as if the evolutionary order of the fossils in the rocks were as well established as the law of gravitation.

Pierce also observed:

> In most places the fault contact is concealed or poorly exposed; but where visible is clean-cut and sharp, with no brecciation of beds above or below . . . the lower contact with the Grove Creek formation is also sharp.[6]

Here also is a repetition, apparently, of the Lewis overthrust contact in Montana and Canada—where good exposures can be found they are usually sharp. Apparently these criteria meant little to the paleontologists of former years, before the impact of structural geology. Now it is recognized that such a major tectonic event as a giant overthrust should exibit such structural or mechanical evidence as tectonic breccia, mylonite, or ground up rock, and slickensides. Along the contacts of all true overthrusts that the writer has observed, these criteria are evident.

How Could a Thrust Break Up into Blocks?

Pierce also described the Heart Mountain thrust as involving many miles of rock movement, because it is now separated into some 50 blocks of lower Paleozoic limestone scattered over a triangular area of 30 by 60 miles. See Figures 2 and 3. The Ordovician is represented by the Bighorn dolomite, and the Mississippian by the Madison limestone, measuring up to 1800 feet in thickness. In most places the thrust block rests on Tertiary rock.

Pierce seemed to think that the blocks became detached by movement. However, it seems a bit anomalous for a thrust block to move when the elements of the thrust block were separated by such great distances. For example the Heart Mountain thrust

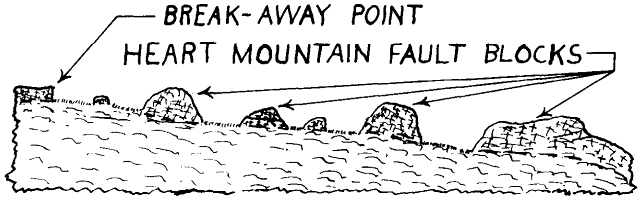

Figure 3. This is a diagrammatic vertical section through some of the blocks and the underlying ground. This is not necessarily drawn to scale; in particular, the vertical scale has been exaggerated.

block is isolated many miles from the nearest like block on McCullouch peak many miles to the east.

In places the Paleozoic thrust block is covered with what geologists call the "early basic breccia"; in other words a volcanic rock, now being eroded. Another puzzle to geologists is that no volcanic fragments have been found between the thrust block and the lower Grove Creek (Cambrian). This is strange if the volcanics had been laid down before the thrust action, which is assumed to have taken place in Eocene time.

Bucher enumerated the many problems of the so-called Heart Mountain Fault:

> There are no known roots for this thrust, no known surface from which it could have been derived. Like the Juras in the Alps, a *decollement*? This fault has uncommon features not accounted for by tectonic movement accompanying low-angle faults.

As already mentioned the absence of the Bighorn, Jefferson, and Three Forks formations, which should lie between the Madison and the Grove Creek formations, seem to indicate to some stratigraphers the presence of a thrust or a glide block, as the only possible explanation for the absence of the missing formations. But this seems to be a very weak form of reasoning. Would it not be a more logical explanation to call in question the veracity of the *must* order of the fossils, that is, the assumed evolutionary order?

According to accepted reasoning, one would have to multiply many times the number of thrust or low-angle faults in the world; for there are numerous cases of missing formations or periods in the world. The Grand Canyon and the Window Rock exposures have already been mentioned.

Recent Observations at Heart Mountain

So far the task has been that of assembling geologic data compiled by other geologists, whose consensus has been that Heart Mountain is an isolated thrust plate, separated from other sections of the same overall thrust by miles. Most geologists have readily admitted the field difficulties with such a concept, but they still cling to the thrust theory on account of the fossil evidence.

Now it is urged that the time is long overdue to take into account also the structural evidence. In the case of Heart Mountain the evidence does not uphold the thrust concept, nor is there any credible support for the idea of gravitational gliding; for a sloping gliding surface is lacking.

Actually the whole area has been serverly folded and deformed. Following the strata westward and to the northwest, one finds the underlying beds dipping around 10 degrees on average to the east and southeast, dipping away from the Absaroka mountain range along the east border of the Yellowstone Park (See Figure 1).

This places the capping strata on Heart Mountain much higher stratigraphically than equivalent limestones to the west. Remember Pierce called this the Cathedral Cliffs formation and, although he placed it on top of the Madison, he believes that the formation moved along with the thrust.

Southwest of and adjacent to Heart Mountain the strata have been so severely deformed that in places they rest on edge. Due to heavy rock slides and fragmentation, the contact of the Madison on Heart Mountain with underlying beds is covered. However, I found one place, on an exposed salient at the west end of the mountain where the contact was nearly visible; except again the limestone rubble covererd the actual contact.

Some geologists, I understand, have interpreted the limestone rubble as tectonic breccia, caused by thrust movement. However, this particular rubble is no different from the erosional rubble all around the steep sides of the mountain. Where the underlying sandstone was exposed it did not show brecciation or mylonite.

The so-called Madison thrust plate is more nearly horizontal than the underlying beds, indicating evidently that that formation was deposited more recently on a truncated surface of the lower beds. This is evidence against the thrust mechanism imagined.

Evidence that Heart Mountain is a Normal Fault

There is decided evidence of fault action at Heart Mountain, but it involves normal fault action rather than thrusting. Approaching Heart Mountain from the south one climbs a long limestone stratum that dips away from the mountain, toward the south; whereas the north side of the mountain has beds that dip the other way, to the north. This began to arouse suspicions that perhaps after all what is involved is not a thrust fault, but a normal fault, a fracture along the apex of an anticlinal fold, a very common occurrence. See Figure 4.

In an anticlinal fold there probably was compression throughout most of the fold, except at the top of the anticline, where in fact there would be tension, resulting in a fracture along the roof of the anticline. Before the fracture took place, however, the greatest tension would have been at the top surface of the fold. Deeper down, conversely, pressure would have compressed the plastic rock, forming a sort of a vertical, longitudinal layer of rock. (I have seen this structure in many fractured anticlines, especially in freshly extruded basalt, which cracks along the top of a lava flow. An example is in the Craters of the Moon volcanic field in Idaho.)

This fracture along the apex of the Heart Mountain fault has been filled with alluvium. I looked for tell-tale evidences of vertical dike or rock slab. I found such evidence in quantity, rather close to the nearly vertical southern escarpment of the Madison formation. This just about settled the issue with me. Here is a normal or vertical fault rather than a thrust fault.

Often with a normal or vertical fault, one side moves vertically with reference to the other side, causing the edges of the strata on one side to dip up, while the other move up. I think this is the case with the Madison cap rock or strata, on top of the Heart Mountain.

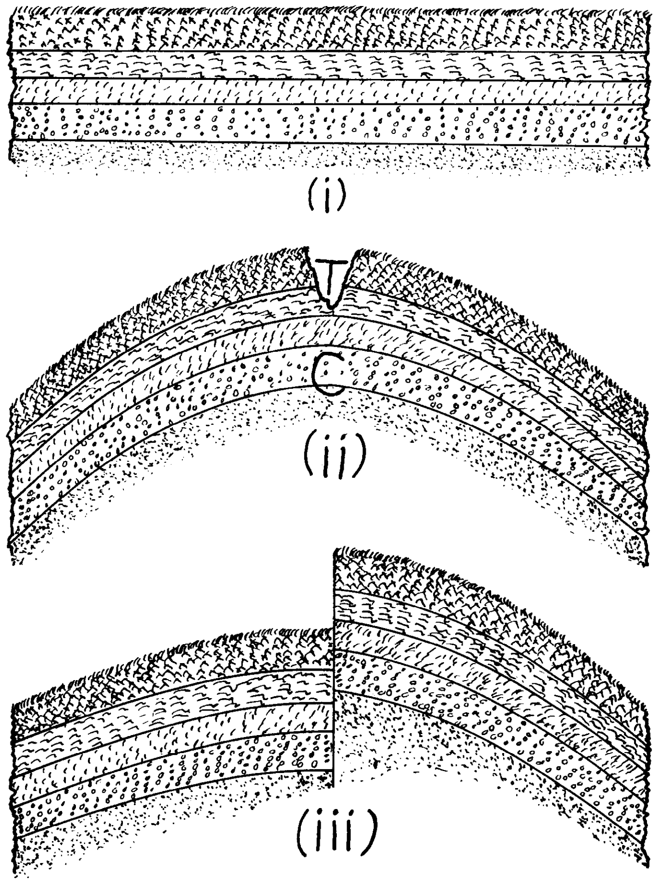

Figure 4. This shows the way in which, it is suggested, these formations actually developed. Originally level strata, as in (i), became bent into an anticline, as in (ii). The rock at the bottom, at the place marked "C", was in compression, and was likely crushed to some extent. That at the top, at the place marked "T", on the other hand, was in tension. Likely a fissure opened due to the tension, as suggested; although the fissure might later have become filled with debris. Still later, the one side slid up with respect to the other, in an ordinary fault, as shown in (iii).

The southern lip of the exposed Madison limestone dips upward at about 10 degrees, whereas the same stratum levels off to about five degrees some distance from the edge. This is more evidence of a normal fault rather than a thrust fault; although both could be admitted if the evidence warranted such a conclusion.

In conclusion I would discount the popular idea of thrust faulting at Heart Mountain, but would interpret the formation as a normal fault at the apex of an anticline.

References

[1]Nicholson, H. Alleyne 1875. Ancient life history of the Earth. Published by Wm. Blackwood of Sons, Edinburgh and London, p. 40.

[2]Geikie, Archibald 1903. Textbook of geology. Fourth Edition. McMillan Co., New York, p. 678.

[3]Pierce, William G. 1963. Cathedral cliffs formation: the early acid breccia unit of northwestern Wyoming, *Bulletin of the Geological Society of America* 74(1):9-22.

[4]Twenhofel, W. H. 1939. Principles of sedimentation. First Edition. McGraw-Hill, New York, Chapter 1, p. 6.

[5]Pierce, William G. 1957. The heart mountain thrust, *Bulletin of the American Association of Petroleum Geologists* 41(4):591-626.

[6]Pierce, *Ibid.*

[7]Bucher, W. H. 1933. Problem of the Heart Mountain thrust, *Proceedings of the Geological Society of America*, p. 57.