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Island arcs, accretionary terranes and Midcontinent structure New understandings of the geologic architecture of the U.S. Midcontinent

Marvin P. Carlson
Research Geologist, CSD

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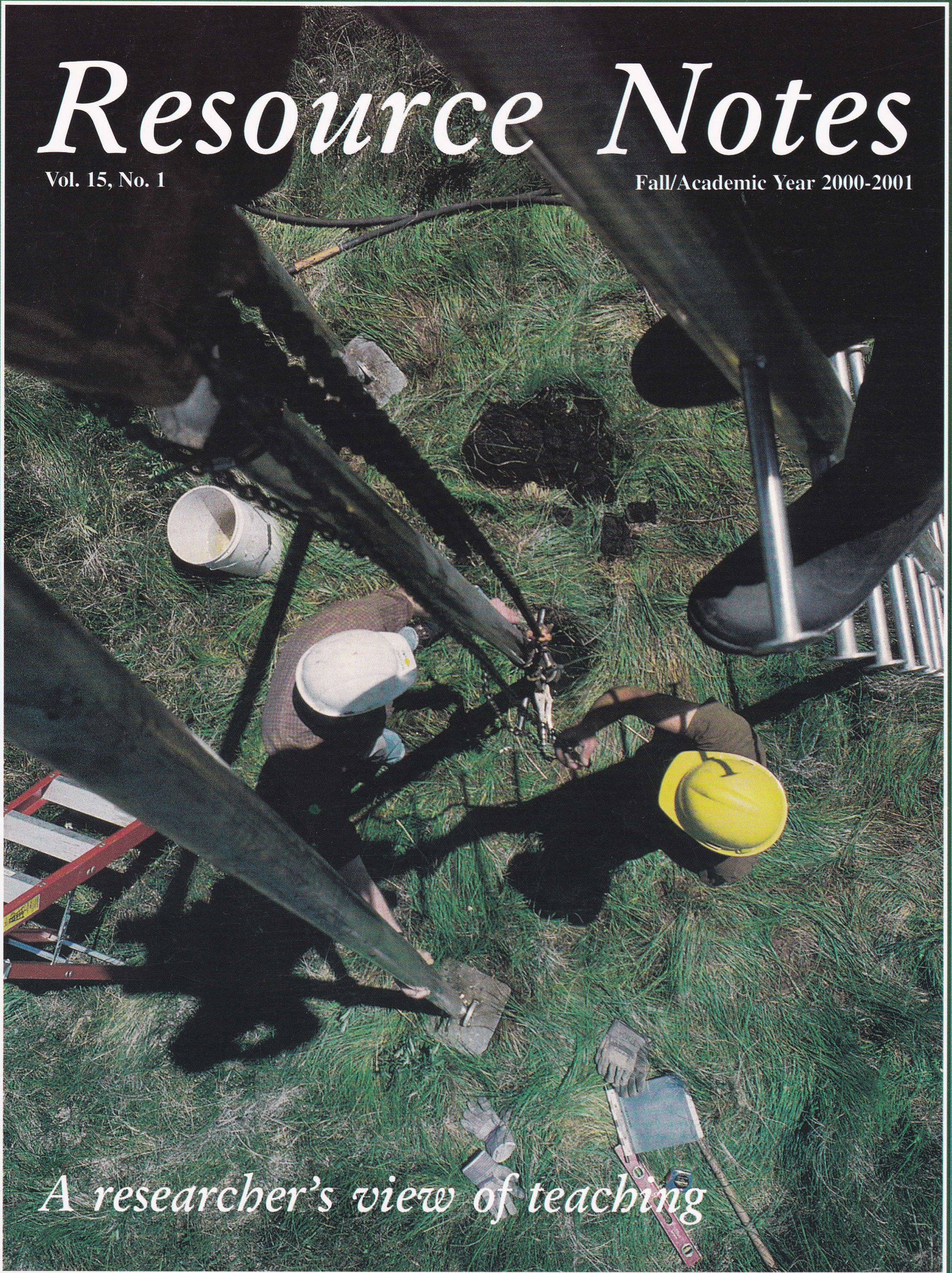

A researcher's view of teaching

The annual news magazine of the Conservation and Survey Division

Accumulation of island arcs key to Midcontinent's structural features

Editor's Note: Marv Carlson, research geologist with University of Nebraska Conservation and Survey Division, has been working on a sweeping re-interpretation of the structure of the deepest rocks beneath the surface of Nebraska and the U.S. Midcontinent in general. If accepted, it could provide a complete explanation for most of the structural features that helped create both the surface landscape and the subsurface, including aiding in the location of oil and gas and other economic minerals.

His ideas rely on major advances in geology that began 30-some years ago with the acceptance of the theory of plate tectonics, the notion that vast continental and oceanic plates on the Earth's crust support major land masses and oceans, or parts of them, as they shift on the heavier and less solid mantle. When these plates bump into each other, they can "bunch up" to create mountains ranges, as with the Himalayas when India hit south-central Asia.

One can also be pushed below another, a process called "subduction." The resulting friction, compression and melting of Earth material also causes folding and faulting that creates mountains and earthquakes, produces hot spots that create volcanoes, volcanic islands, geysers and hot springs, among other features, and intense heat and pressure that can produce rare or precious minerals. Traps created by faults and folds can also hold oil and gas that migrates upward.

Carlson has proposed at several professional meetings that, similar to what is now going on in the Pacific with Japan and the Philippines as they move closer to Asia, island arc material has at various times accumulated on the southern margin of what would become the North American continent, producing the southward growth of this continent. He believes the sutures, or joining, of these island arc complexes to the continent, created during collisions with the continent, have been reactivated to form the major structural features in the Midwest, Great Plains and mountain West of the United States. He is also preparing scholarly papers on these subjects. In the following article, he presents these ideas to a general audience. -- CF.

Island arcs, accretionary terranes and Midcontinent structure
New understandings of the geologic architecture of the U.S. Midcontinent

by Marvin P. Carlson
Research Geologist, CSD

A data base collected over the last 100 years, containing both surface and subsurface information, has allowed us to begin to understand the physical framework of Nebraska. We have learned that even in the stable Midcontinent region of North America, there has been an active geologic history. This framework has been deciphered by our programs of surface geologic mapping and by the study of rock samples from both water wells and those deeper test wells for oil and gas. Determining the major structural features across the state (figure 1) has allowed us to better understand both the occurrences of its natural resources and natural hazards.

It has been a more difficult problem to explain the process by which this physical framework was established. The last 500 million years of our geologic history is recorded in sedimentary rock layers of sandstone, limestone and shale. These units record an active history of deposition, uplift and erosion. However, it is the older, crystalline igneous and metamorphic rocks of Precambrian age that control the zones of structural weakness across the state. Only by understanding the history of these much older "basement" rocks – their composition and their method of formation – can we explain the current architecture of our state and possibly anticipate where future activity might occur.

More than 2,200 deep holes

We have in Nebraska more than 2,200 deep holes that have penetrated into these older crystalline basement rocks. Depth to these rocks varies from 600 feet to more than 10,000 feet across the state. Most of the wells were drilled in search of oil and gas, and the Conservation and Survey Division has long been active in acquiring the records and the actual rock samples from these drillings. Analysis of these rock fragments for their mode of occurrence and their chemical composition allows some interpretation of the environment and processes in which they were formed. Most of the crystalline basement rocks under Nebraska were formed between 1.78 and 1.60 billion years ago. The nature of the rocks suggests that they were formed as accretionary arc material (an arc of islands that accumulated) onto the older core of North America. Eventually, this material was sutured (joined itself) to the continent. This pattern of plate tectonics would have been somewhat similar to the process by which island arcs such as Japan and the Philippines are gradually approaching and eventually will accrete onto Southeast Asia.

A series of island arcs

The available dates from our Precambrian rocks show progressively younger rocks from about 1.8 billion years in the north to about 1.61 in the south. Thus it appears that there were a series of island arcs that accreted (accumulated) and provided a southward growth to North American across what is now Nebraska. Sutures (joints) were created by each collision of an island arc and the following accretion onto the continent (figure 2). Each of these sutures continued to be a zone of weakness in the crys-

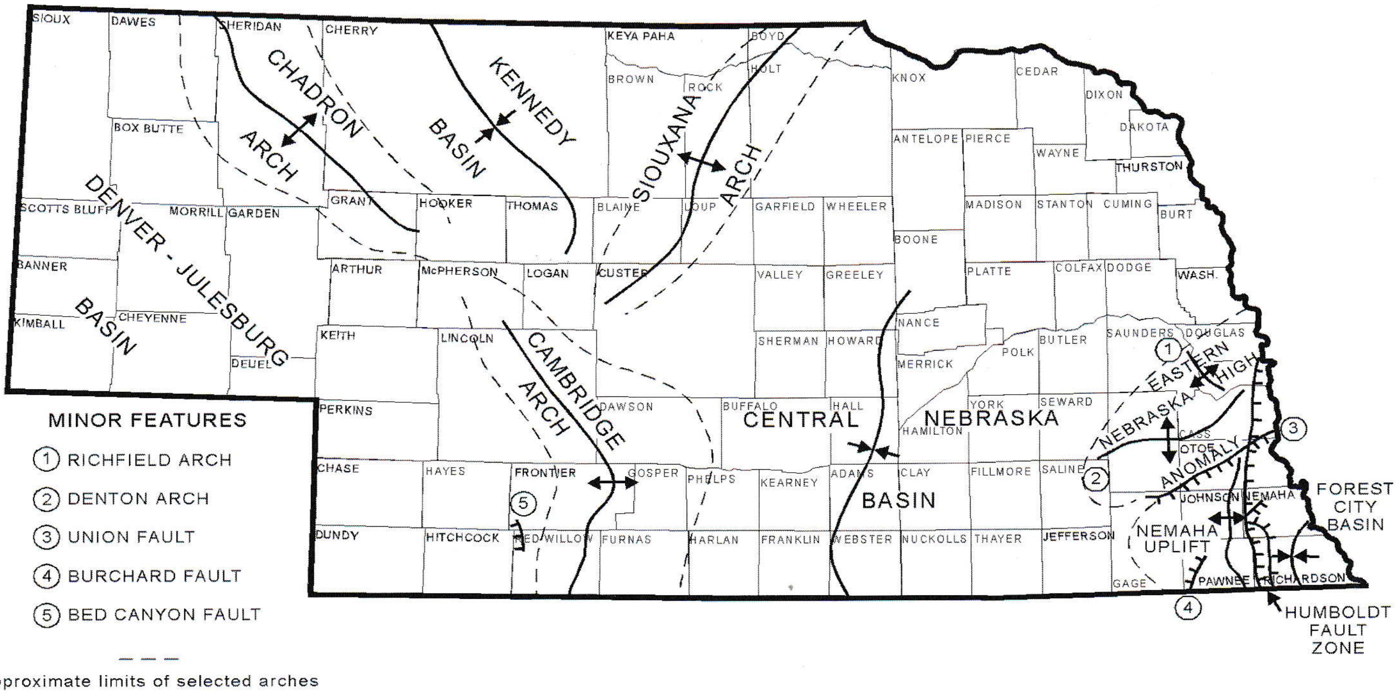

Fig. 1. Principal structural features of Nebraska

talline basement rocks. These zones were reactivated repeatedly during our more recent geologic history and controlled the structural activity now present in our younger rocks. Figure 3 illustrates the relationships between the basement suture zones and some of the important structural features in the Nebraska area. The more complicated structural pattern in southeastern Nebraska is a product of reactivation associated with the 1.1 billion-year-old Midcontinent Rift System. This feature is still very old but much younger than the accretionary basement history of the rest of our state.

Throughout our geologic history, North America has contacted, collided and reacted with other continental and oceanic plates, each interaction creating stress across the continent, including folding and faulting. The reactivation of older weak zones in the basement created uplift and shifting of the margins of the ocean basins. These activities, in turn, controlled the depositional

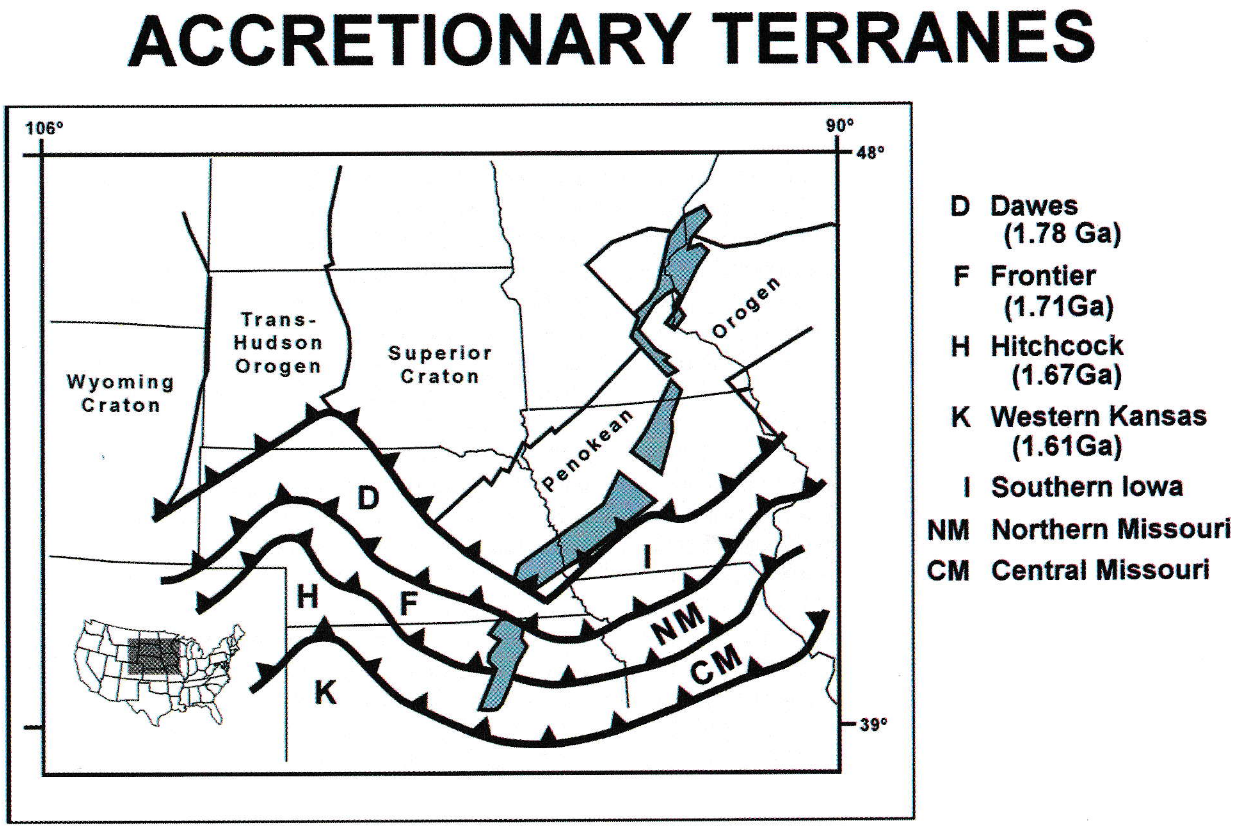

Fig. 2. Accretionary (accumulating) terranes in the Midcontinent. Gray area is Midcontinent Rift System.

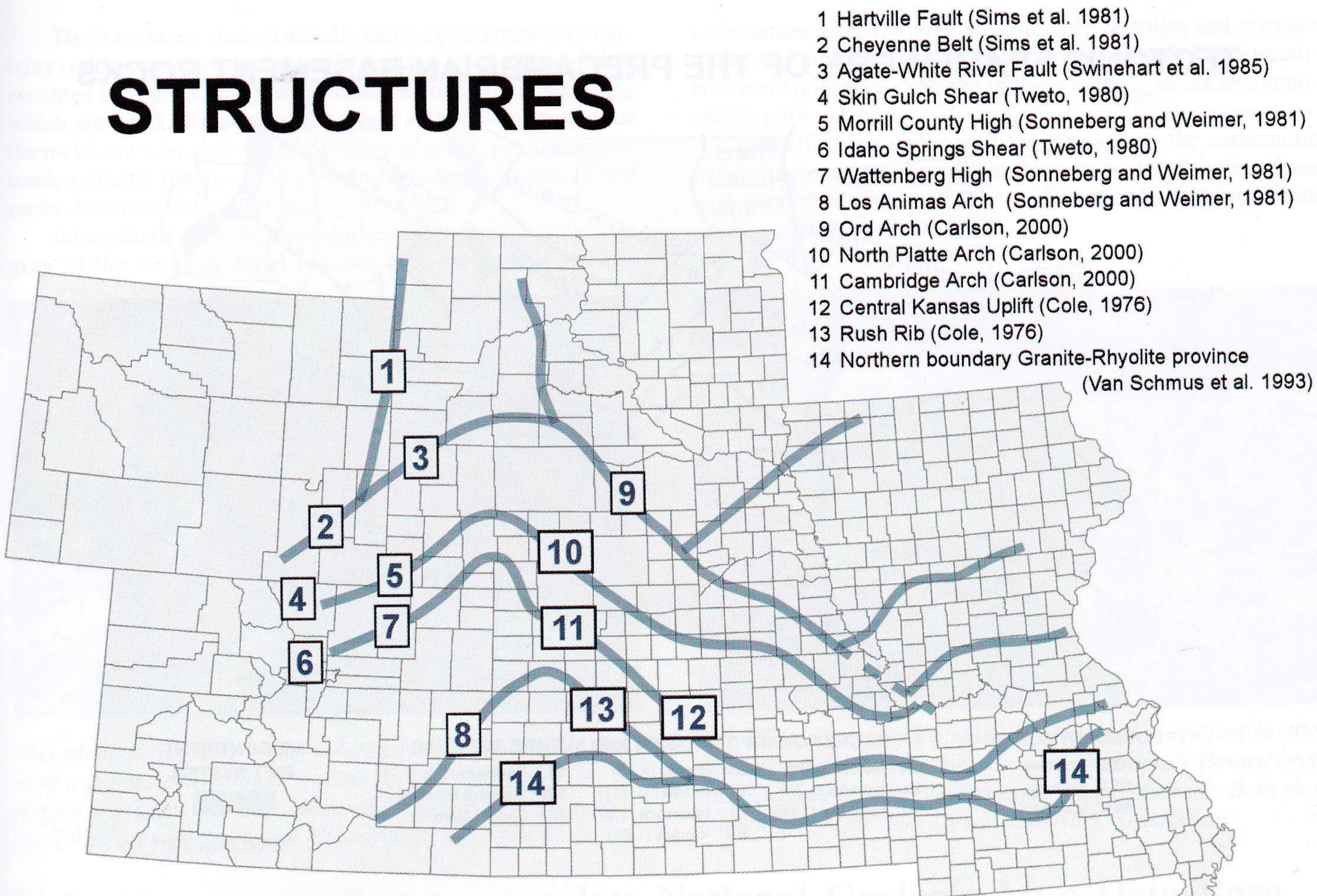

Fig. 3. Structures in the architecture of the Midcontinent related to accretionary terranes

and erosional patterns of the rock sequence that now contains Nebraska's mineral, petroleum and water resources and serves as parent material for its soils. In addition, this tectonic pattern influences our drainage patterns and marks the location of natural hazards such as earthquakes and landslides.

Several families of arcs

As our research has extended across the continent, we propose that during this time period (1.8 to 1.6 billion years), there were several families of accretionary arcs moving from the southwest, south and southeast. Each family consisted of a series of island arcs that accreted and contributed to the southward growth of North America. Interference between these arcs created boundary zones that, similar to the accretionary sutures, are weak zones in the crystalline basement rocks. These boundary zones are now the location of the tectonic weak trends that have been reactivated to create the Rocky Mountains and a similar subsurface feature across Nebraska and Kansas, the Nemaha Uplift (figure 4; next page). If accepted, this proposed detailed subdivision and pattern of growth of North America will significantly advance the interpretation of the region's geologic history. Much better explanations, and predictions, for the younger geologic history of both Nebraska and our continent will be provided based on the pattern of reactivation of the fundamental weak zones in the crystalline basement. *(Continued on next page; see figure 4.)*

Division fact sheets brief, general-audience publications; single copies free

The Conservation and Survey Division has begun publishing a new series of informative flyers called "Earth Science Notes." Generally 4-6 pages, the fact sheets are offered for free as single copies or for a small fee for multiple copies. They will focus on specific topics from a range of subjects such as water supply, transfer and quality, climate and environmental change, land-cover and land-use analysis and soils and geological investigations.

"We want to offer concise treatments of a range of topics to a public more and more swamped with information," explained Mark Kuzila, CSD director. "In addition, there is a list of more resources for those who want them."

Fact sheets are available on the effects of environmental change on climate, water and carbon storage and on test drilling in Nebraska, explained Charles Flowerday, CSD editor. Another is being developed on the sale and transfer of water in Nebraska. Suggestions on Earth science topics of interest are welcome, he added. For more information, contact the division at 113 Nebr. Hall, Univ. of Nebr.-Lincoln, 68588-0517, or phone (402) 4727523, or email: csdsales@unl.edu.

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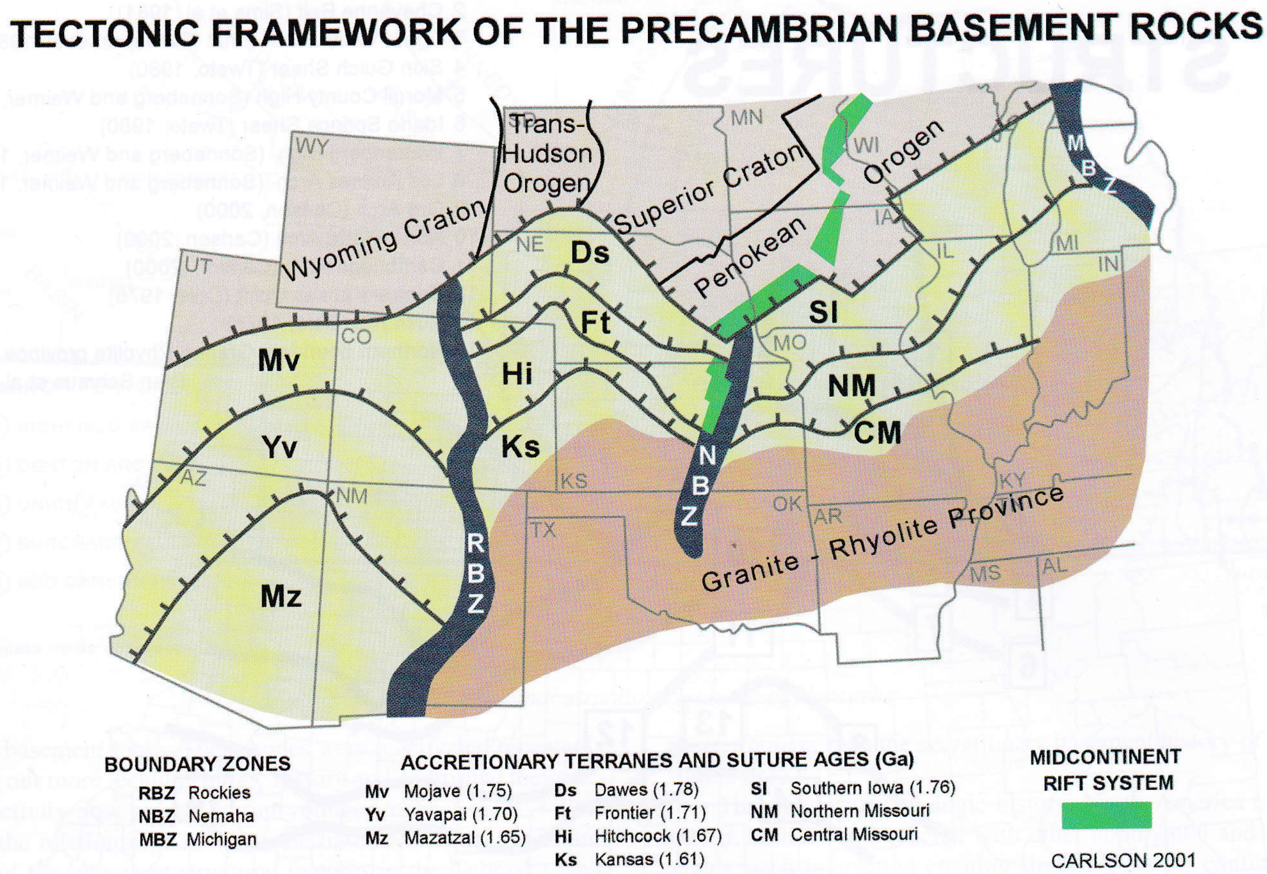

Fig. 4. Tectonic framework of the Precambrian basement rocks

Editor's Note **-- Treves puts some of the deepest rocks in the state under the microscope.**

Another geologist mixing and matching teaching and research, with partial appointments to the University of Nebraska-Lincoln Conservation and Survey Division (CSD) and its Department of Geosciences (25 percent each), is Sam Treves, formerly chair of the then Department of Geology. Igneous petrology – the origin, occurrence, structure and history of igneous rocks – is his specialty. He teaches Optical Mineralogy and Igneous and Metamorphic Petrology for the UNL Department of Geosciences and is working with Ron Goble of geosciences on some very alkaline rocks from southwestern Canada. He is also working with Goble, CSD colleagues and a graduate student on some ancient and deeply buried rocks in southeastern Nebraska. This work dovetails with Marv Carlson's on the structure of the state's older rocks *(see p. 15)*. It also yields some dramatic microscopic photographs of thin slices of rocks he is studying. -- CF.