

Visual metaphors in structural geology provide avenues for understanding [2013, in Krantz, R., and Boonstra, D., (eds.), 3D Structural Geologica Interpretation, Earth, Mind, and Machine: AAPG Hedberg Research Conference, Reno, Nevada, June 23-27, AAPG Hedberg Research Conference]

Structural geology focuses on deformation of the earth's crust, at all scales, and seeks to interpret geologic structures and 3D forms in terms of tectonic boundary conditions and the behavior of materials in response to force and stress. At the heart of structural geological interpretation is deformation, i.e., the overall transformation of an original rock body to its final deformed state, taking into consideration changes in location, orientation, shape, and size. Tests of the efficacy of interpretations of deformation, e.g., deformation expressed as folding and faulting, involve restorations of deformed 3D geologic forms to their original state(s). Structural geologists place a high premium on effective 3D visualization skills and strategies, given the inherent 3D geometric complexity of strongly deformed rock bodies and the practical limitations imposed by incomplete exposures. Because of these objectives and challenges, training of students in structural geology, and textbooks on structural geology, place strong emphasis on deducing 3D forms and constructing 'movement-plans' for how 3D forms evolved. For my own teaching of undergraduate structural geology, I design cartoons (visual metaphors) intended to have students grasp the basic tenets of a new term, form, method, concept, or geologic process. The visual metaphors 'ease' the student from the ordinary and familiar to the extraordinary and unfamiliar. The cartoons can convey understanding literally in seconds. The *2013 Hedberg Conference on 3D Structural Geologic Interpretation (Earth, Mind, and Machine)* caused me to examine literature on conceptual metaphors in order to learn what it is about them that tends to accelerate learning and new understanding.

Colleagues in cognitive science, linguistics, and psychology increasingly hold the view that conceptual metaphors are modes of thought, not just modes of language or figures of speech, and they reflect the fundamental way we think and act. Conceptual blending theory, for example, asserts that our minds continuously blend and integrate vital relations from diverse scenarios, and this is what allows us to 'see' connections between the familiar and unfamiliar. In point of fact, the most powerful conceptual metaphors are analogical comparisons of *relationships* between objects, not simply comparisons of *attributes* of objects. With the fruits of this literature survey in mind, I examined 55 conceptual metaphors in my textbook, *Structural Geology of Rocks and Region*, arranging them in a hierarchy of 'orders' from lowest-order literal-similarity matches (e.g., shape attributes of conical fold, compared to ice cream cone) to higher-order metaphors conveying analogical relatedness (e.g., structural analysis of a pepperoni pizza). I concluded that the conceptual metaphors most effective in grounding the 3D visualization of forms and shapes are ones that express 'kinematics', i.e., movement and change. When the kinematics of creation of final 3D forms is grasped, it becomes easier to visualize the complete 3D forms, even when only small bits of the final forms can be observed in the field or in the

subsurface. But here is a larger message that goes far beyond structural geology. The challenges of communicating tenets of structural geology to new learners is analogous to communicating across disparate disciplines. If communication across the sciences is going to work, we need to speak in the language of analogy; otherwise, we will not be able to communicate at all (McShea, 2013).