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Panta Rhei – the changing face of rocks (Stephan Mueller Medal Lecture)

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The Earth's lithosphere changes shape continuously by plate tectonics and other processes but, unfortunately, we cannot directly access the deeper parts of our planet to study this evolution and the active deformation processes involved. Indirect, geophysical observations allow us to reconstruct processes on a larger scale, but the details on a smaller scale must be studied from samples of metamorphic rocks that have travelled to the surface by complex paths, being modified along the way. Structural analysis of metamorphic rocks has helped to unravel deformation mechanisms and the associated geometric, mineralogical and geochemical changes, but even so there remains a lot to be learned: For example, we know little about the formation of porphyroblasts and their relation with the surrounding fabric, or of porphyroclasts, mineral fish, foliations, lineations, flanking structures, strain fringes and other vorticity gauges; likewise, on a larger scale, the development of gneiss domes, and complex ductile shear zones is poorly understood. This may seem a problem for specialists only, but it actually concerns all large-scale tectonic studies, since the geometry of deformation structures is the "tool-box" of tectonic reconstructions.

Recent tectonic processes and large-scale changes in the arrangement of lithospheric fragments are relatively well understood, because we can rely on direct observations of current processes. However, the further we go back in time, down to the Archean, the more we rely on incomplete data obtained from metamorphic rocks that have been preserved. In many cases, deformation geometries in rocks are the single witnesses available of ancient tectonic processes and history, and their correct interpretation is therefore of crucial importance. Without a reliable structural geology toolbox, it is not possible to correctly interpret early, especially Precambrian tectonic processes. This will be demonstrated with examples from Namibia and Australia.

Clearly, our understanding of the way in which rocks flow and of the evolution of their final deformation geometries must be improved. One problem is that in tectonics, as in other studies, research is increasingly and briefly directed towards a few highly specialised isolated phenomena that are in the focus of attention, ignoring the huge gaps in our knowledge that separate these. This situation can be improved by the application of new and multidisciplinary research methods, by the identification of "natural experiments", and by more integrated, systematic studies of the connection between structures that at first glance may seem unrelated. These techniques, however, will mostly tell us what happens on the crystal-to-metre scale, while they reveal little on the scale of orogenic belts and continents. For the latter, we need field observations, although there are currently multiple developments that conspire against the progress of field-based studies. Field studies are time consuming in an age where results must be published rapidly, and are hampered by inclement weather and instable local political situations. In addition there is a lack of field-adapted information collection and long-term storage tools. Fortunately, this can now be improved dramatically with the application of drones, photogrammetry and field-adapted mapping software, which in combination can build and store a permanent database of deformation structures, to use in present and future studies. Hopefully, this combination of improved collection and processing of field-based data and a systematic improvement of our understanding of the development of deformation geometries will enhance our fundamental knowledge of flow in rocks. Then, finally, will we begin to understand how everything moves - *panta rhei*!