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Society Announcements

Arizona Geological Society – 14 January 2021 Presentation

Mineral District and Orogenic Evolution in Arizona

Jan Rasmussen and Stan Keith (MagmaChem Research Institute)

ZOOM URL - <https://arizona.zoom.us/j/87210212100>

Day: Thurs, 14 January 2021

Time: 6:30 p.m. (Admittance to ZOOM from 6:00 p.m. on)

Abstract: Page 3-4

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Continued on Page 2

Publication News

Have you visited the [AGS Publications Archive](#) lately? We are posting more OCR format guidebooks that were carefully scanned by former AGS President Kevin Horstman (deceased). Please contact Publications Committee Chair Cori Hoag (corihoag @ [msn.com](mailto:corihoag@msn.com)) if you have others to scan that you don't see in the chronological list of guidebooks. The recent additions are:

- Arizona Geological Society, 1981, [Patagonia - Red Mountain - Hardshell deposits](#): Arizona Geological Society Symposium, Tucson, 1981, Relations of tectonics to ore deposits in the southern Cordillera, Arizona Geological Society and University of Arizona mine tour and field trip data for field trip no. 8, March 21, 1981, Guidebook, Leaders - J. Quinlan, F. Koutz, and R. Corn, variously paged.
- Keith, S. B., 1984, [Tertiary tectonics of the San Manuel-Kearny region, central Arizona](#): Arizona Geological Society Field Trip, April 13-15, 1984, Guidebook Leader S. B. Keith, 100 p.
- Dummett, Hugo, and Colburn, Nora, leaders, 1988, [Field trip to Bighorn mine, Socorro mine, and Copperstone mine, Arizona](#): Arizona Geological Society Spring Field Trip, April 17, 1988, Guidebook.
- Force, E.R., and Dickinson, W.R., 1993, [New work in the San Manuel and Mammoth districts \(Pinal County, Arizona\) - An introduction via Tucson Wash](#): Arizona Geological Society Spring Field Trip, Tucson, Ariz., March 21, 1993, Guidebook, 53 p., scale 1:24,000, 1 sheet.

Member News

The [Mining Foundation of the Southwest](#) held a virtual **38th Annual American Mining Hall of Fame Awards Ceremony** on December 5, 2020. The 1-hr program is available for viewing on the home page. The honorees included:

- Inductee, Lukas Lundin, Chairman Lundin Group of Companies
- Medal of Merit, Emily King, CEO, Global Venture Consulting, Founder Prospector
- Medal of Merit under 40, Mine Manager, Cortez Operations, Barrick Gold Corporation
- Industry Partnership, Hexagon Mining
- Mining's Past
 - Noah S. Kellogg (1831 - 1903), Prospector and Discover of Bunker Hill Mine
 - John Barry "Black Jack" Newman (1862 – 1928), Developer of Miami Copper Company
 - Lemuel Coover Shattuck (1866 - 1938), Miner, Rancher, Merchant, Banker
 - Albert J. (Al) Perry** (1930 - 2013), Exploration Geologist Al was a former long-time AGS member and Councilor (1975-1978). Please watch his short video tribute at 18 minutes followed by remarks by AGS member **Donald Earnest**.

MFSW also prepared a 4-minute [In Memoriam video tribute](#) for four other notables including geo-statistician Dr. Harry M. Parker, metallurgist Dr. Roshan Bhappu, and AGS members and exploration geologists **J. David Lowell**, and **Robert A. Metz**.

Mineral District and Orogenic Evolution in Arizona

Jan Rasmussen and Stan Keith (MagmaChem Research Institute)

ABSTRACT

The authors were asked by Ray Grant to write a chapter on Arizona geologic history and prepare mineral district maps for the 4th edition of *Mineralogy of Arizona*, to be published by the University of Arizona Press in 2021 or 2022. The author's 3-year effort resulted in a complete revision of the Arizona metallic mineral district map originally published by Keith and others in 1983 as Bulletin 194 from the Arizona Bureau Geology and Mineral Technology (now Arizona Geological Survey). The 1983 map presented for the first time outlines drawn around areas of metallic meganeralization of a certain age and metal type that typically correlated with a specific suite of igneous rock of the same age as the mineralization (the igneous suites were not shown at the time). The map was designed to be geologic and not to simply designate an area of historical mining activity as had been traditionally presented in previous literature.

Major additions to the mineral district map that are presented in the 4th edition include outlines for non-metallic and petroleum systems, which are also considered mineral systems. Mineral system compositional data was combined with chemical and mineralogical information for temporally and spatially associated magmatism. The magmatism was classified into Peraluminous and Metaluminous megaserries and then into Quartz Alkalic, Alkali-Calcic, Calc-Alkalic, and Calcic series and in selected cases, oxidized and reduced mini-series (Keith and others, 1991; Keith and Wilt, 1986; Keith and Swan, 1995). This approach allowed a systematic grouping of metallic production data and mineralogical occurrences into the mineral district map units.

Inspection of the county maps revealed contiguous areas of the same type of magmatism, metals, and age dates that are called super-systems, These super-systems probably are related to deeper, underlying batholiths. Some groupings of super-systems are called mega-systems. The mega-system units are large enough to be considered mini-metallogenic provinces and generally are not mixed with any other mineral system type. The mineral district maps in the 4th edition of *Mineralogy of Arizona* have information for each district about the igneous rock association, metals present, and age of the deposit in Ma.

The mineral district maps introduce another new type of mineral district system: the ultra-deep hydrothermal (UDH) system. These gigantic systems are crustal in scale and represent various fractionations of massive hydrothermal fluids that in part are related to serpentinization processes deep in, or at the base of, the crust (the Serpentsphere of Keith and others, 2008). Such UDH systems include regional dolomitization (e.g., Epitaph System in southeastern Arizona), saline deposits (Holbrook basin in northeastern Arizona), chemical black shale deposits (e.g., Yellowbird graphite-graphene deposit in west-central Arizona), and hydrothermal oil systems (e.g., Dineh bi Keyah oil field in northeastern Arizona). UDH systems appear to be maximized during extensional rift episodes that tap deep mantle sources.

Compilation of the maps was done using stratotectonic analysis in the sense of Keith and Wilt (1986) and the magma-metal series classification presented by Keith and others (1991). This compilation revealed that at least 14 orogenic episodes or cycles affected Arizona through time, beginning about 1840 Ma, as recorded in zircons from the Elves Chasm orthogneiss of the western Grand Canyon. The research also revealed that the oldest geologic material in Arizona is not a rock, but is the mineral zircon. Detrital zircons as old as about 3.796 Ga have been extracted from the Vishnu Schist in the eastern Grand Canyon. This date suggests the sediments containing the zircon were derived from the Wyoming craton to the north of Arizona. The compilation also indicated that at least 4 periods of rifting or attempted rifting are present that intervene between the orogenic events.

The orogenic/rift parade is summarized in Table 1. Each member of the orogenic parade can be generally divided into 3 phases:

1. Metaluminous magmatism related to steep or steepening slab subduction;
2. Peraluminous (two-mica granite) magmatism related to flat subduction.
3. Epeiric uplift and erosion forming major erosion surfaces beneath regional unconformities that separate the orogenic events. Mature continental sediments (sandstones or quartzites) generally occur on the unconformities, and immature arkosic clastic and chemical, carbonaceous, black shales were deposited, along with mafic magmatism, in the rift sequences.

Each of the above phases can be combined into an orogenic cycle, of which at least 14 are currently recognized. Thirteen of the 14 orogenic cycles are fundamentally compressive in nature, whereas one (the San Andreas orogeny) is fundamentally transpressive in nature, and can be divided into transpressive fold ranges (e.g., the transverse ranges of west-central Arizona) and transtensional, horst-graben domains.

The variety of resource specialties in Table 1 shows that Arizona is not characterized by a preferred metallogenic bias, such as copper. For example, through geologic time, only two porphyry copper events (early Jurassic and Laramide) are associated with metaluminous magmatism in the geologic record, whereas at least five tungsten (minor beryllium) events are associated with granite systems of peraluminous affinity. Hence, Arizona through time is characterized by metallogenic heterogeneity and should not be considered only a copper metallogenic province. The porphyry copper cluster instead should be considered a region of smaller copper clusters interspersed with lead-zinc-silver and tungsten (beryllium) clusters.

Keith, S.B. Gest, D.E., DeWitt, E., Toll, N.W., and Everson, B.A., 1983, Metallic mineral districts and production in Arizona: Arizona Bureau of Geology and Mineral Technology (now Arizona Geological Survey), Bulletin 194, 58 p., 1:1,000,000 map.

Keith, Stanley B., and Wilt, J.C., 1986, Laramide orogeny in Arizona and adjacent regions: a strato-tectonic synthesis, in Beatty, B., and Wilkinson, P.A.K., editors, *Frontiers in geology and ore deposits of Arizona and the Southwest*: Arizona Geological Society Digest, v. 16, p. 502-554.

Keith, S. B., Laux, D. P., Maughan, G., Schwab, K., Ruff, S., Swan, M. M., Abbott, E. W., and Friberg, S., 1991, Magma series and metallogeny; a case study from Nevada and environs, in Buffa, Ruth H., and Coyner, Alan R., editors, *Geology and ore deposits of the Great Basin; field trip guidebook compendium*: Geological Society of Nevada, Reno, NV, p.404-493.

Keith, S. B., and Swan, M. M., 1995, Tectonic setting, petrology, and genesis of the Laramide porphyry copper cluster of Arizona, Sonora, and New Mexico: *Arizona Geological Society Digest* 20, p. 339-346.

Keith, S.B. and Swan, M.M., 1996, The Great Laramide Porphyry Copper Cluster of Arizona, Sonora, and New Mexico: the tectonic setting, petrology, and genesis of a world class porphyry metal cluster, in Coyner, A.R., and Fahey, P.L., eds., *Geology and Ore Deposits of the American Cordillera: Geological Society of Nevada Symposium Proceedings*, Reno/Sparks, Nevada, April, 1995, p 1-80.

Keith, S.B., Swan, M., Rueslatten, H., Johnsen, H.K., and Page, N., 2008, The serpentosphere: *Geological Society of Nevada newsletter*, v. 23, no. 3, p. 3.



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