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Review of Characteristics and Genesis of Lithophysae

SUN Wenyan(孙文燕)[1,2], ZHANG Xueyi(张学义)[3]

1) *School of Earth Science and Resources, China University of Geosciences, Beijing, 100083, China*
2) *ARC Centre of Excellence in Ore Deposits, University of Tasmania, Hobart 7001, Australia*
3) *School of Earth Sciences, The University of Melbourne, Victoria 3010, Australia*

1 Introduction

Spherulite, lithophysae and thunderegg are three kinds of relevant terms. Thunderegg was probably first known through agate gem enthusiasts and collectors. The name “thunderegg” was created by local Warm Springs Indian Tribe in Oregon, who believed the myth that thundereggs were missiles from the thunder-gods in their volcanic quarrels. Actually, the Indians’ “missiles” here were volcanic bombs. However, thundereggs were paragenetic with the material they were found in rather than volcanic bombs. Then, geologists recognized thundereggs as lithophysae, which are associated with spherulites. But many problems arise, for example, how irregular or star-shaped cavities form, how materials are transported to fill the centers of cavities by mineral crystals?

Spherulites, lithophysae and thundereggs have been found and researched in many places of America (e.g. Utah, California, Michigan, New Mexico, Oregon, Colorado, Nevada, and Idaho), and other countries of the world, such as, Mexico, United Kingdom, Italy, Iceland, Australia, Greece, South Africa, and India. Besides the research about the origin, characteristics and forming conditions of spherulites, lithophysae and thundereggs, experiments also have been carried out to investigate the influence of Lithophysae or lithophysal cavities have on the mechanical properties of the welded tuffs, which are used as repository for high-level radioactive nuclear waste (e.g. Yucca Mountain, Nevada, the U.S.). However, there have been controversial about the definition and relationship between thundereggs and lithophysae.

2 Definition and Characteristics

2.1 Spherulites

Definition: Spherulites are typically rounded or spherical aggregates of acicular crystals radiating from a single point.

Characteristics: Spherulitic textures are dominantly radial textures but not necessarily spherical. There are five categories: (a) axiolitic spherulites (spherulitic fibers radiate from a plane); (b) fan spherulites (with fibers radiating from a point); (c) bow-tie spherulites (Two fan-like arrays are joined at their apices); (d) plumose spherulites (showing extensive side branching. Unlike dendrites, branching does not occur on crystallographic axes); (e) spherical spherulites.

Crystals of spherulites are commonly composed of alkali feldspar and silica minerals (such as cristobalite, quartz). The size of spherulites ranges generally from a few millimeters to 1-2 cm.

2.2 Lithophysae

Definition: Lithophysae (singular lithophysa,

Email: sunwenyan1004@gmail.com

Greek for rock bubble), associated with spherulites, are generally radial or concentric cavities that is hollow, or partly to completely filled with later minerals.

Characteristics: As defined above, lithophysae are kinds of (large) spherulites with radial or concentric cavities. The diameters are a few centimeters up to tens of centimeters. Large examples (over 3.66m) are also reported. Lithophysae have ellipsoidal to spherical external shapes. They often appear single, however, intergrown twins, triplets and even quadruplets are also documented. The form of the cavities may range from simple spherical which is commonly seen, to squarish-shaped, geometrical, even more complex star pattern. The shells are dominantly composed of quartz and feldspar. Minerals occur in lithophysae cavities are generally quartz, opal, chalcedony, amorphous silica, chlorite, feldspar, and calcite; accessory minerals include tridymite, topaz, sanidine, hematite, thorite, specularite, orthoclase, fluorite, biotite, white mica, barite, sphene, saponite, rutile, muscovite, magnetite, jasper, epidote, cristobalite, beryl, cassiterite, celadonite, agate, adularia, spessartine-almandine garnet, pseudobrookite, bixbyite, and ilmenite.

2.3 Thundereggs

Definition: As defined by previous stydies, thundereggs are solid lithophysae lacking radial structure and filled with secondary silica (quartz or chalcedony).

It has been long debated about the terms of lithophysae and thundereggs. Whether lithophysae are simply geological term of thundereggs or they are different things is still uncertain. However, lithophysae or thundereggs could be considered as a type of spherulites formed under certain circumstances.

3 Theories of Lithophysae/Thundereggs Genesis

Spherulites, lithophysae and thundereggs often occur in silicic or felsic volcanic rocks, such as rhyolite, ignimbrite, rhyolitic lava, obsidian, perlite, tuff, and pitchstone. They are not found in comparatively silica-poor rocks.

Spherulites may form by heterogeneous nucleation (e.g. submiroscopic seed crystals, bubbles, or fractures) in a highly supercooled viscous melt, or by devitrification of silicic glass.

3.1 Formation of the shells

There are three hypotheses about the genesis of the shells. First, the formation of shell was due to immiscible silica at magmatic temperatures. Second, the shell was “colloidal substances” around a nucleus (rhyolite phenocrysts or vapor bubbles). Third, the shell was composed of intergrown spherulites.

3.2 Formation of the cavities

The origin of lithophysal cavities has been controversial for a long time.

One debated aspect of the origin of cavities is whether they were primary or formed through a later leaching process. Richthofen who created the term “lithophysae”, considered that cavities were induced by expansion of gas released from a hydrated viscous flow. Iddings (1887) demonstrated the primary origin of the cavities. However, he deduced the cavities formed by a volume reduction accompanying crystallization and dehydration. Swanson et al. (1989) studied lithophysal cavities in the Inyo Dome, California, attributed the cavities to both volume loss and volatile exsolution. Another option is that extensive spherulitic growth is due to vesicles nuclei.

Another controversial point is between the expansion theory and shrinkage theory. Cavities were due to expansion of increasing vapor pressure as a result of crystallization (in this process water became immiscible and was exsolved as an aqueous vapor) in the expansion theory. While in the shrinkage theory, cavities were formed by contraction in a cooling rhyolite. Ross (1941) attributed the cavities to the combination of increasing pressure due to released volatiles (caused by crystallization of anhydrous feldspar and cristobalite) and shrinkage as a result of cooling of the enclosed material.

3.3 Formation of the minerals in the cavities

The models for the minerals formed in the cavities are dominantly by (a) a rhythmic crystallization in the interior of cavities and (b) fluid infiltration through cracks or microscopic pores in the shells.

4 Summary

As described above, the author considers thundereggs are a general term of lithophysae, and lithophysae are a geological term of thundereggs. Spherulites are small spherical mass which can be component of lithophysae.

Several hypotheses have been proposed about the origin of lithophysae/thundereggs. However, there is not a systematic model to explain the whole process. The following studies should aim to confirm: (1) The relationship between the lithophysae/thundereggs and surrounding groundmass. Are they paragenetic or lithophysae formed in a later stage? (2) Initiation of the immiscibility. (3) The source of minerals deposited in the cavities and the mechanism of mobilization of the materials.

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