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PSEUDOKARST IN THE 21ST CENTURY

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Abstract: Karst is a specific type of terrain (or landscapes) with characteristic suites of well-known surface and subsurface dissolutional features. The latter result from integrated subsurface drainage. A variety of nondissolutional processes forms terrains analogous to certain types of karst; these are termed pseudokarst. Before 1906, these generally were believed to be karst somehow formed in poorly soluble rocks. They share a considerable range of features, resources and values with karst, commonly (but not invariably) including caves, and the two are linked across a wide spectrum of processes and features (e.g., between dissolutional and piping caves). Unlike karst, integrated subsurface drainage may not be present. Isolated caves define neither karst nor pseudokarst. Multiprocess terrains and landscapes are not uncommon. Based largely on conclusions of a working session of the 1997 International Congress of Speleology, eight types of pseudokarst are identified, with notably different implications for extraterrestrial habitats: rheogenic pseudokarst, glacier pseudokarst, badlands and piping pseudokarst, permafrost pseudokarst, talus pseudokarst, crevice pseudokarst, compaction pseudokarst and consequent pseudokarst. Some appear to exist on Mars. Speleologists expert in their differentiation should serve as consultants to planetary geologists.

Introduction

The 65th anniversary of the National Speleological Society also is the 65th Anniversary of the use of the term pseudokast in the title of a scientific article (Floridia, 1941). Now, studies of pseudokarst and pseudokarstic caves constitutes a rapidly expanding subdivision of speleology. Numerous articles in publications of the National Speleological Society concern pseudokarst and its caves in lava, in and under glaciers, in seacoasts, in badlands and landslide topography, crevice caves and terrains in a variety of rocks, and even multiprocess caves. In part, this trend has resulted from emphasis on pseudokarst in planetary geology, but many are fascinating in their own right. The International Union of Speleology now has a full-fledged Commission for Pseudokarst as well as another Commission on Volcanic Caves, and a third which maintains that seemingly pseudokarstic glacier features actually are karstic, not pseudokarstic.

History

Landforms now generally recognized as pseudokarstic were written about in China perhaps 2,300 years ago (Liu et al., cited by Pewe et al., 1995) and at Italy's Mount Etna only a little later (Carus, T., cited in Banti, 1993). A map of Iceland's Surtshellir system was published in 1759 (Halliday, 2004). During the early 20th Century the term originated independently in several European languages, for several types of features and widely varying terrains. The German geologist von Knebel (1906) appears to have been the first to use it in print, identifying crevice terrain in Iceland which engulfs a river as pseudokarstic. Many of these early writers were far from centers of learning and were not academics. Commonly their accounts were in obscure publications. Many were in languages which were not widely read. Locally invented terminologies tended to baffle readers, especially those which attempted to apply karstic concepts to phenomena which only looked karstic.

Beginning around 1927, Russian scientists pioneered the study of karst-like features in permafrost and in poorly soluble rocks. In 1931 and 1935 F. P, Savarenskij wrote about karst-like phenomena in loess and clayey sediments, terming them loess karst and clay karst (Savarenskij, 1931, 1935 [cited by Alexander Klimchouk, written comm.]). In 1947, N. A. Gvozdetskiy recommended qualified use of the term pseudokarst, correctly pointing out that its processes are real, not pseudo. A breakout occurred in mid-century when central European speleologists began publishing English-language summaries, then entire papers in English (e.g., Kukla, 1950; Kunsky, 1957). Vulcanospeleology developed separately, with initially discrete Italian and American roots which merged as a result of international symposia beginning in the 1970s. Initial momentum in glaciospeleology also had a separate beginning, entirely European. In July 1886 Forel mapped a newly discovered 250-meter cave in the Arolla Glacier at 1:5000, and described and discussed it a year later (Forel, 1887). In 1892, a glacial outburst from the Tete-Rousse Glacier killed some 150 Swiss villagers. The Director of the Mont Blanc Observatory investigated and found a glacier cave 175 m long leading to a drained glacial lake (Anon., 1892; Vallot et al., 1892). In 1895 Sieger followed with a lengthy article entitled *Karstformer der Gletscher*. It summarizes several earlier reports of glacier caves in various parts of the world (Sieger, 1895). Three years later, proceedings of

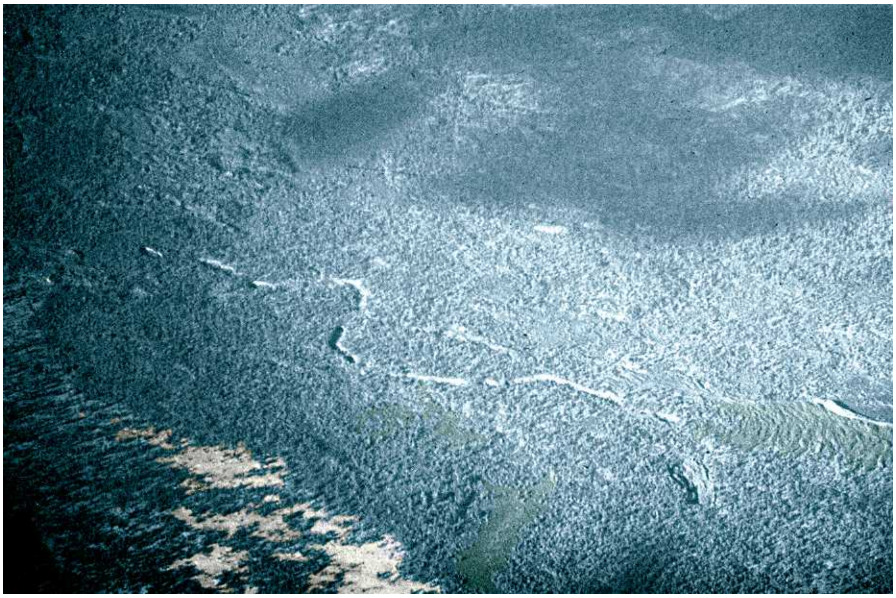

Figure 1. Rheogenic pseudokarst. Oblique aerial photo of partially collapsed lava tube cave, El Malpais National Monument, New Mexico. Compare with Figure 7 showing rectilinear crevice pseudokarst.

a symposium on glacial hydrology were published in Spelunca No. 16.

DEFINITION

A working session of the 1997 International Congress of Speleology concluded that "pseudokarsts are landscapes with morphologies resembling karst, and/or may have a predominance of subsurface drainage through conduit-type voids, but lack the element of long-term evolution by solution and physical erosion" (Kempe and Halliday, 1997). Not clearly covered by this definition, however, are some landscapes arising in talus with an active streamflow (e.g., Colorado's Lost Creek Cave System, discussed below). An older, simpler definition now seems more desirable: karst-like morphology primarily produced by a process other than dissolution.

TYPES OF PSEUDOKARST

On a global basis, the 1997 working session specifically identified:

1) rheogenic pseudokarst (pseudokarst on lava flows)
2) glacier pseudokarst
3) badland and piping pseudokarst (including loess)
4) permafrost pseudokarst
5) talus pseudokarst (including boulder fields and roofed streamcourses)

Time limitations precluded consideration of two other important types, and a third is identified here for the first time:

6) crevice pseudokarst (including littoral pseudokarst)
7) compaction pseudokarst
8) consequent pseudokarst

Other pseudokarstic types exist (e.g., tower pseudokarst, as discussed by Wray [1997]).

RHEOGENIC PSEUDOKARST

Rheogenic pseudokarst includes those portions of lava flows which are shaped by the presence of open lava tubes (Fig. 1). Its caves and pits include lava tube caves, hollow tumuli, hollow lava rises, hollow flow lobes and tongues, open vertical volcanic conduits, tree and animal mold caves, hollow hornitos, and a very few hollow dikes. Spaciousness and near-level floors of numerous terrestrial lava tube caves suggest that they may be a major extraterrestrial resource (Halliday, 1966). The Commission on Volcanic Caves of the International Union of Speleology has taken a proactive approach to identification and documentation of rheogenic caves and pits throughout the world, and a global file of maps of lava tube caves is funded by NASA and maintained at Arizona State University.

In the last half-century, studies of lava tube caves have revealed that they are resources scarcely second to dissolution caves, with many features in common. Some contain a greater range of minerals than do karstic caves and some contain biota as specialized as those of karstic caves and mesocaverns. While significant differences exist in their hydrogeologic mechanisms, lava tube caves pose virtually the same disease hazards as dissolution caves. A few contain cave art, habitations, fossil localities and other cultural features. Others are notable recreational sites including show caves.

Figure 2. Glacier pseudokarst. Multiple entrances to the Paradise Ice Cave system ca. 1970.

The longest known lava tube cave is Hawaii's Kazumura Cave which has a slope length of 65.6 km. Never more than 20 m below the surface, it has a vertical extent of 1,100 m. Its floor plan basically is sinuous, with local braiding. It is especially notable for drained plunge pools up to ~20 m wide. The deepest known open vertical volcanic conduit is Iceland's Thrinukagigur, 204 m deep. Hawaii's Na One pit crater contains a smaller open vertical volcanic conduit which begins on a ledge near the bottom of the pit crater. Their combined depth is 268 m. Divers have descended 122 m in the water-filled vertical conduit of Hawaii's Kauhako Center, with the bottom beyond reach of their lights.

Other volcanic islands with especially notable rheogenic pseudokarst and caves include Iceland, Honshu (Japan), Jeju Island (Korea), Azores Archipelago, Canary Islands, Comoro Archipelago, Galapagos Archipelago, Samoa and Rapa Nui (Easter Island). Major continental sites include Italy (Mt. Etna), Kenya and Australia. Other locations include Syria, Jordan, Saudi Arabia, Rwanda, Chile, Argentina and Tanzania where a unique carbonatite rheogenic pseudokarst exists in the crater of Ol Doinyo Lenggai volcano. In the conterminous United States, notable rheogenic pseudokarst is present in most of the states west of the Great Plains (Montana and Wyoming are exceptions; a single open vertical volcanic conduit recently was identifield in Nevada, and to date, examples of this type of pseudokarst in Colorado are minor).

Glacier Pseudokarst

Glaciospeleology is the study of caves and streams within and beneath glaciers and firn (Fig. 2). Fountain and Wilder (1998) have provided an excellent overview albeit with minimal reference to caves. Current studies are especially active in Iceland, Greenland (especially of moulins), Svalbard (Spitzbergen), Siberia and southern South America. Such studies have lagged in Antarctica where the world's largest glacier cave either underlies the Ross Ice Shelf or is the intraglacial cave containing Lake Vostok. Geothermal caves on Mount Erebus are receiving increasing study. U.S. Geologic Survey geologist, Israel Russell, was the father of American glaciospeleology. He produced several notable reports on the 4,000 km^2 (1,500 mi^2) Malaspina Glacier in Alaska (e.g., Russell, 1893) with special reference to their caves and hydrogeology. A long hiatus followed Russell's work, but additional glacier pseudokarst was found in Alaska and elsewhere in the northwestern United States and in the part of British

Columbia bordering the Alaskan panhandle. Aside from the small, anomalous low-elevation Big Four Ice Caves (Washington State), the most accessible was on 4,392 meter Mount Rainier. Its well-known Paradise Ice Caves originally were in a terminal lobe of its Paradise Glacier. By 1908 attractive pictures of these caves adorned local guidebooks. Also, geothermal caves were identified in craters of several northwestern volcanoes. The largest were atop Mount Rainier. On Oregon's Mount Hood, gas emissions in such a cave are lethal at least intermittently (Anonymous, undated, reprinted, 1994a). Geothermal caves of Mount Baker were found and studied much later.

In the 1940s, the Paradise Ice Caves at the snout of the Paradise Glacier disappeared as their lobe shriveled and vanished. A few years later, similar caves were found in the nearby Stevens Glacier. Through the 1950s and 1960s they gradually enlarged and the name Paradise Ice Caves was transferred to them. Also on Mount Rainier, an outburst flood from a previously unknown cave in the Kautz Glacier caused considerable damage, but decades passed before the flood and the new-found cave were correlated. Much the same happened on Oregon's Mount Hood in 1921 (Anonymous, undated, reprinted 1994b).

The year 1968 marked the beginning of a short golden era of American glaciospeleology centered in the Alaska-British Columbia ice fields (e.g., MacKenzie and Peterson, 1968) and on the new Paradise Ice Caves (e.g., Anderson et al., 1994). In the latter, Anderson and co-workers found and mapped a total of almost 25 km of ephemeral passages. These passages appeared, enlarged into spacious rooms, collapsed and disappeared as this glacier lobe also shriveled, expanded, shrivelled again and finally disappeared. Maximum length at any given time was 13.25 km (Anderson et al., 1994). Ice speleothems and glare ice and firn inclusions in the glacier were especially notable features. Part of the system reappeared briefly in firn in the mid-1990s.

In 1970, climbers, cavers and geologists became interested in geothermal ablation caves in the summit craters of Mount Rainier. Eugene Kiver and co-workers mapped 1.8 km of passages in the east crater and 305 m in the smaller west crater. It contained a small lake at an altitude of 4,329 m. Evaluating mudflow hazards, Lokey (1973) spent 42 consecutive days in these craters and their caves.

Studies of similar, comparatively accessible caves in the crater of Mount Baker were underway when Mount St. Helens erupted in 1980. The impact of the eruption refocused all northwestern speleological activity, and no further work has been done in the Mount Baker geothermal caves.

BADLANDS AND PIPING PSEUDOKARST

Piping is the horizontal, graded or vertical grain-by-grain removal of particles by channelized ground-water flow in a granular material and in some poorly soluble rocks (Fig. 3). Parker and Higgins (1990) and Dunne (1990, p. 1–28) present different mind-sets and different vocabularies in the same volume. It long was recognized primarily as a cause of serious engineering problems. In recent years, extensive piping caves have become recognized as important individual features. Piping was first recognized in loess and loess-like silt in China, but natural caves are not characteristic of loess topography.

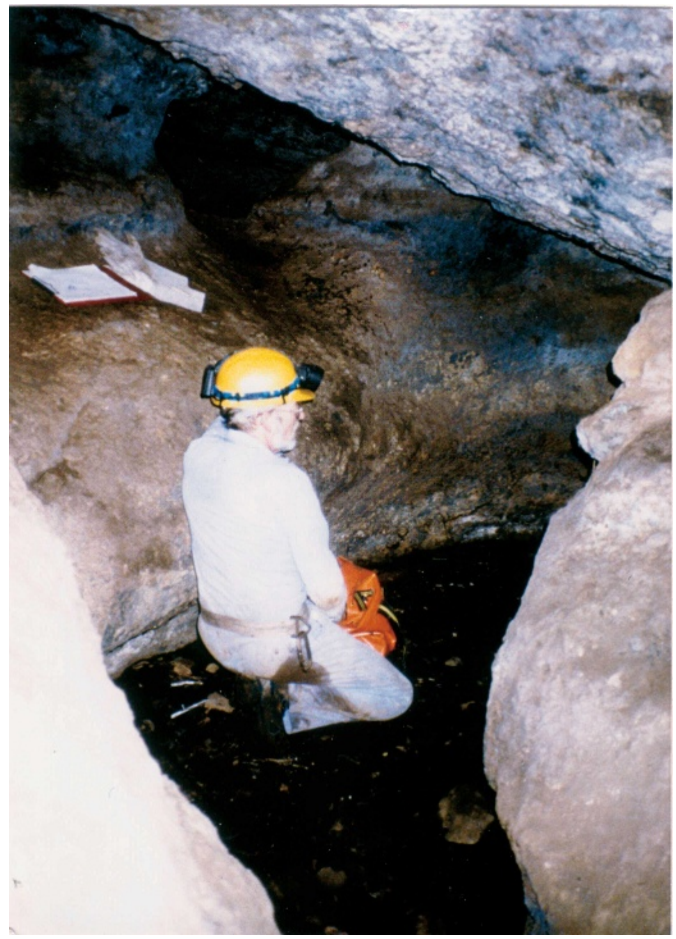

Figure 3. Gigglers Caves, Kenya, a piping cave in hard granular tuff.

The pure form of piping is the pseudokarst extreme of a speleogenetic spectrum with 100% karstic dissolution at the other. Between these extremes is an intermediate interface in impure carbonates and evaporite rocks and limy sandstones and other poorly soluble rocks. Piping also participates in development of large multiprocess caves in some tropical quartzites and in development of compaction pseudokarst (see below).

Some badlands topography is riddled with pipes, piping caves, funnel-shaped sinks, dry valleys and other features of centripetal subsurface drainage commonly observed on karstic terrains. Locally these form specific landscapes. Many of their individual features are short-lived; some last only from one storm to the next. The overall landscape, however, tends to persist through long periods of scarp

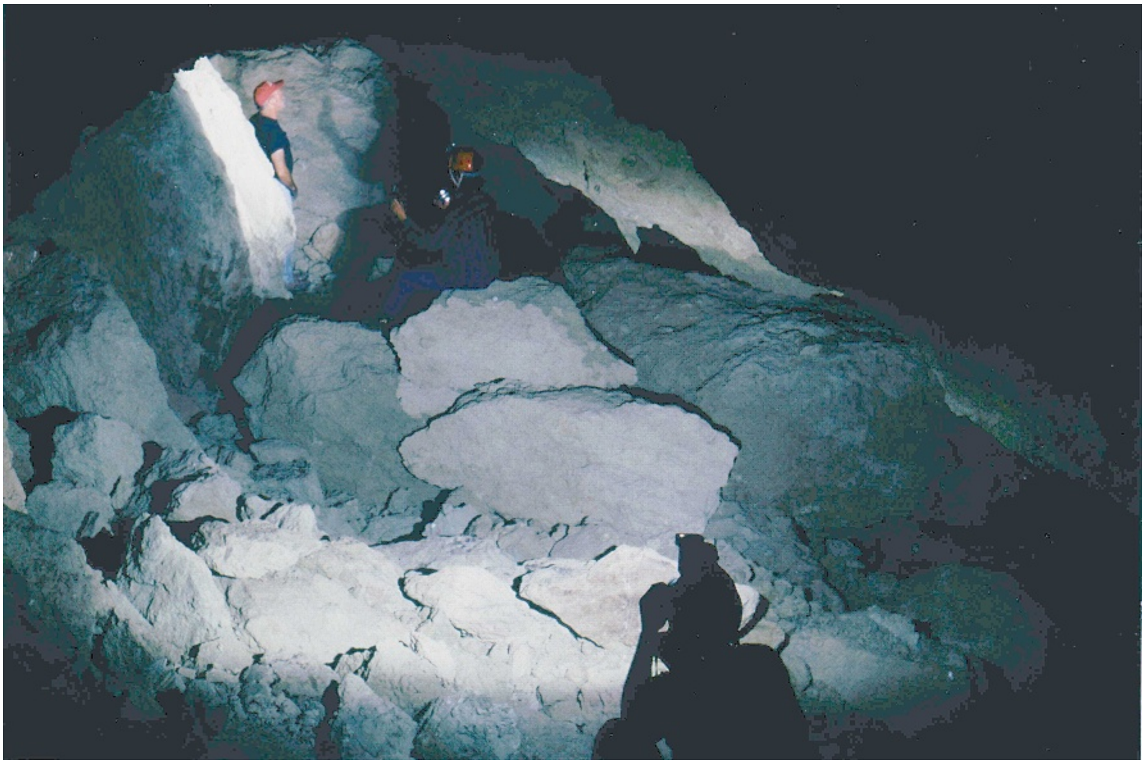

Figure 4. Small room in Officer's Cave, Oregon, a piping cave in a pyroclastic landslide. In more consolidated rock with less frequent rockfall, piping caves may provide extraterrestrial shelter.

retreat. Badlands National Park (South Dakota) is the American type locality, and Petrified Forest National Park also contains notable examples. In Oregon's John Day Country, 345-meter Officers Cave (Fig. 4) was described as an isolated geological curiosity in 1964 (Parker, 1964). A few years later, Texas and California speleologists began describing increasingly large, complex piping caves in a variety of poorly consolidated dry lands. Beginning with Anvil Points Claystone Cave in 2001, Davis unleashed a seeming flood of reports on examples in drylands in western Colorado (e.g., Davis, 2001). Pipes also are common in boglands, with slutch caves up to 50 m long reported in England. The longest recorded American piping cave is 804 m Christmas Canyon Cave, formed in a thin layer of unconsolidated volcanic ash between a surficial basalt layer and a mudflow deposit. It serves as a seasonal resurgence for much of the Cave Basalt lava flow on the south side of Mount St. Helens, Washington (Halliday, 2004).

In more consolidated rocks, piping forms complex caves in sandstones in Minnesota and Arkansas, and participates in formation of others in hard granular tuff and in partially soluble lakebed deposits in Kenya. The latter include Kitum Cave, formerly believed to have been excavated by elephants seeking salt. Perhaps the longest piping cave on record is 8 km Bohemia Cave in New Zealand, said to have been formed largely by ground-water erosion in phyllites underlying marble.

Permafrost Pseudokarst

Roughly 10% of the earth's surface is underlain by permafrost. In areas where it is covered by tundra or taiga, a combination of thawing and piping produces curvilinear thaw ponds, steep-walled depressions, funnel-shaped pits, ponors, dry valleys, small caves and other karst-like features. These are largely of interest as engineering problems, but Russian and some other geologists have discussed them specifically as important pseudokarst features. Somewhat similar features are present where residual soil of melting glaciers takes the place of tundra or taiga. In Europe, the term thermokarst has been applied to permafrost pseudokarst, but there is nothing dissolutional in the processes which form any of it. Marjorie Sweeting is among those who have decried this unfortunate term, pointing out its confusing similarity to thermal karst.

Talus Pseudokarst

Talus caves are receiving increasing attention in the world speleologic literature, but talus pseudokarst is rarely mentioned. Nevertheless, talus accumulations occasionally form important landscapes and American speleologists tend to underestimate the occurrence and significance of talus caves per se (Fig. 5). In some parts of Europe, they are the largest and commonest type of cave. Sjoberg (1989a) found that 15% of Swedish talus caves have high scientific and/or recreational values; Sweden's Bodagrottorna has more than 2,500 m of passage. In temperate climates such caves may serve as important glacieres or provide other microclimates favorable to specialized life forms. In arid regions, some minimize evaporation of running or ponded water. Especially in granite and anorthosite, some provide delightful recreational caving. A few have been developed as show caves. In Southern California and probably elsewhere, some talus caves served as human habitations well into the 20th Century.

In the United States, talus caves exist almost exclusively in one of two settings: hillside or cliff-bottom rockpile fields which form talus pseudokarst, and steep-walled stream gullies. Sjoberg (1989b) also described neotectonic boulder caves in Sweden. Some of these are end products of roches moutonnees, smoothed and rounded by glacial erosion, then fractured by tectonic activity after deglaciation. This combination of processes has preserved the overall contour of the roche moutonnee, and produced a localized talus pseudokarst.

Rockpile and rockslide talus caves characteristically are slope failure features found especially in boulder fields at the bases of cliffs, on slopes or in narrow stream gorges, or, rarely, in narrow grabens. A variety of processes is involved: block glide, grusification of granite, and others. Some represent a stage of disintegration of crevice caves affected by differing rates of downslope movement. In California and in parts of the northeastern United States, those partially filling narrow, steep-walled granite gorges are locally termed, purgatory caves. Some of these are active multiprocess caves, with active vadose solution, grusification, piping and scouring of talus and bedrock alike. The alpine Lost Creek system of Colorado has formed a distinctive narrow dendritic pseudokarst 5 km long, with large pseudokarstic windows, flat-stacked boulders and ridges of partially grusified granite up to 60 m high. Here, Lost Creek repeatedly disappears into swallet caves, reappearing to flow across flat-bottomed sinkholes (Hose, 1996). Enormous quantities of granitic sand debris have been cleared from caves and sinkholes in this unusual system. Smaller examples have been described in Europe.

Malin and Edgett (2000) have reported several Martian features resembling certain terrestrial talus pseudokarst. Some are immediately downslope from presumed outbursts of water. These are potential Martian glaciers. Others may serve as small habitation sites.

CREVICE PSEUDOKARST

The first identification of a terrain as pseudokarst described a crevice pseudokarst in Iceland (von Knebel, 1906). Where karst and karstic caves are readily accessible, however, all but the most spectacular crevice caves and crevice pseudokarst (e.g., Fingal's Cave, Island of Staffa, Scotland) are commonly ignored. Consequently they are much more common than is generally recognized. They occur in both littoral and inland terrains; the former includes littoral zones of now-dry inland Pleistocene lakes. Littoral examples are formed by hydraulic wedging by waves and other forms of marine erosion. These may form fractures extending hundreds of meters inland, readily traceable on the surface (Fig. 6). Especially where sinkholes develop along such fractures, small but interesting pseudokarstic landscapes may be identified. Examples include the island of Staffa, Scotland, the Ballybunion coastal area of Ireland, sections of the Oregon coast including the Devil's Punchbowl and the area of Sunset Cliffs, San Diego County, California. Because of their origin and geometry, few such caves are inhabitable.

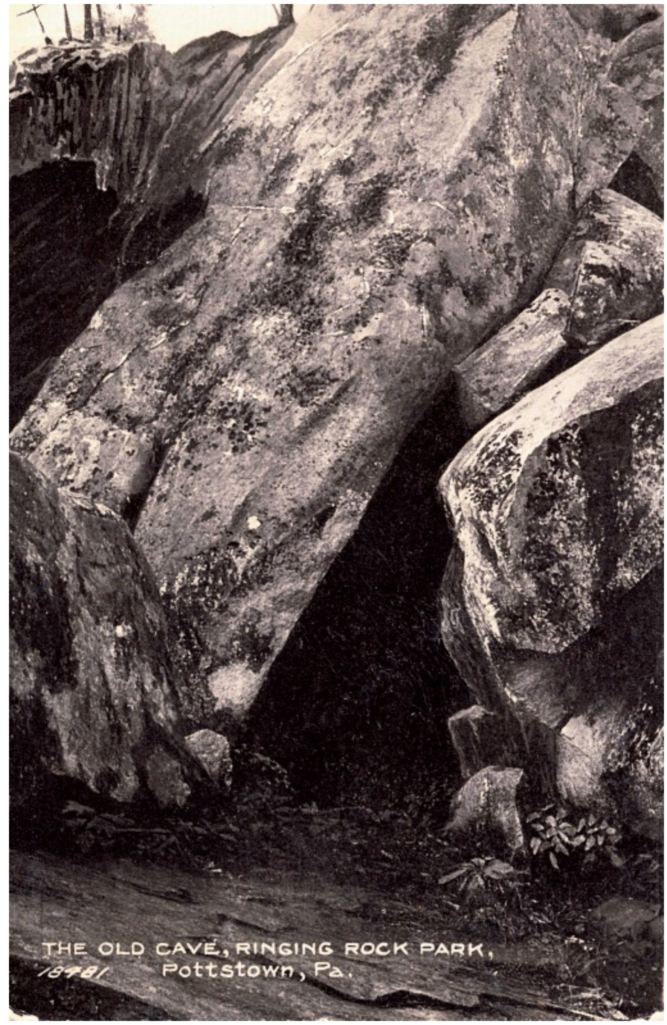

Figure 5. Talus pseudokarst at Pottstown, Pennsylvania. Because the general public is more interested in talus caves than are speleologists, old postcards are a useful resource in identifying them.

Inland crevice caves vary greatly in size. A few have extraordinary parameters, such as Devil's Hole in the small Nevada section of Death Valley National Park. The small near-surface section of this feature is complex and karstic, but most of it consists of a single spacious crevice in

Figure 6. Littoral crevice pseudokarst, island of Staffa, Scotland. The right hand opening is the entrance to Fingal's Cave.

limestone occupied by warm ground water apparently much more than 100 m deep (the National Park Service prohibits cave diving here). It apparently formed as a result of structural tension in the Great Basin and its water is part of a major regional aquifer (Riggs et al., 2000).

Smaller inland crevice caves vary from isolated cracks in cliffs to narrow rectilinear networks on slopes. Many of the latter are an intermediate stage of breakup of competent rock masses due to mass movement or gravity-sliding enhanced by local subsurface drainage. Where the movement is not uniform across the length of such a crevice, bedrock blocks slide and rotate at different speeds and in different directions, converting part or all of crevice caves into one or more talus caves. Basalt and granite commonly develop curvilinear crevice caves rather than rectilinear forms. Some deep caves in tropical quartzite are crevice caves, but others are multiprocess caves extensively modified by piping. Crevice terrains in Arizona appear to be of one of two types. Some in northern Arizona are believed to be the product of subsidence caused by deeply buried karst. Others in areas of especially deep alluvium appear to be the result of excessive drawdown of ground water (Harris and Allison, 2006). Tectonic and solutional caves occur along the former.

Most of the island of Hawaii lacks surface drainage as a result of crevice pseudokarst formed as a result of fractures in brittle basalts secondary to various volcanic and seismic events. Most of these crevices are concealed by vegetation or by volcanic ash, or by subsequent lava flows. But the Great Crack in the southwest rift zone of Kilauea volcano is a kilometer-wide zone of en echelon crevices of various widths and depths, locally open to the surface (Figs. 7 and 8). An implausible concept of its origin is that the weight of Kilauea volcano is tilting that part of the island of Hawaii away from Mauna Loa volcano, and that Kilauea volcano ultimately will slide or topple into the Pacific Ocean. More plausible is the possibility that this is a self-propagating crevice, enlarged and elongated by injection of pressurized magma into initially small fractures in the wall of Halemaumau crater. Within it, mapping teams have reached a depth of 183 m. At several levels, one or more lateral coatings or lava reveal lateral flow of lava at depth. The Great Rift of south central Idaho is another very large inland crevice in a basalt flow field (Fig. 9). At least one eruptive fracture on Mount Etna (Italy) extends downslope in the form of a lava tube cave (Giudice and Scalia, 1994).

Unless block glide has been active, crevice caves characteristically taper downward. Localized floors generally are formed by wedged breakdown blocks. Thus extraterrestrial crevice caves are unlikely to be suitable habitation sites.

Compaction Pseudokarst

Compaction is common in landslide and avalanche deposits. This facilitates piping (see above). Pseudokarst may be formed by such compaction, and is discussed here for the first time. Initially, drainage of such deposits tends to be internal and their surfaces may be pitted with large and small punched out or conical crater-like depressions (Fig. 10). A notable example formed in unconsolidated material at the northern base of Mount St. Helens (Washington State) on May 18, 1980. Here, virtually the entire northern side of the volcano avalanched moments

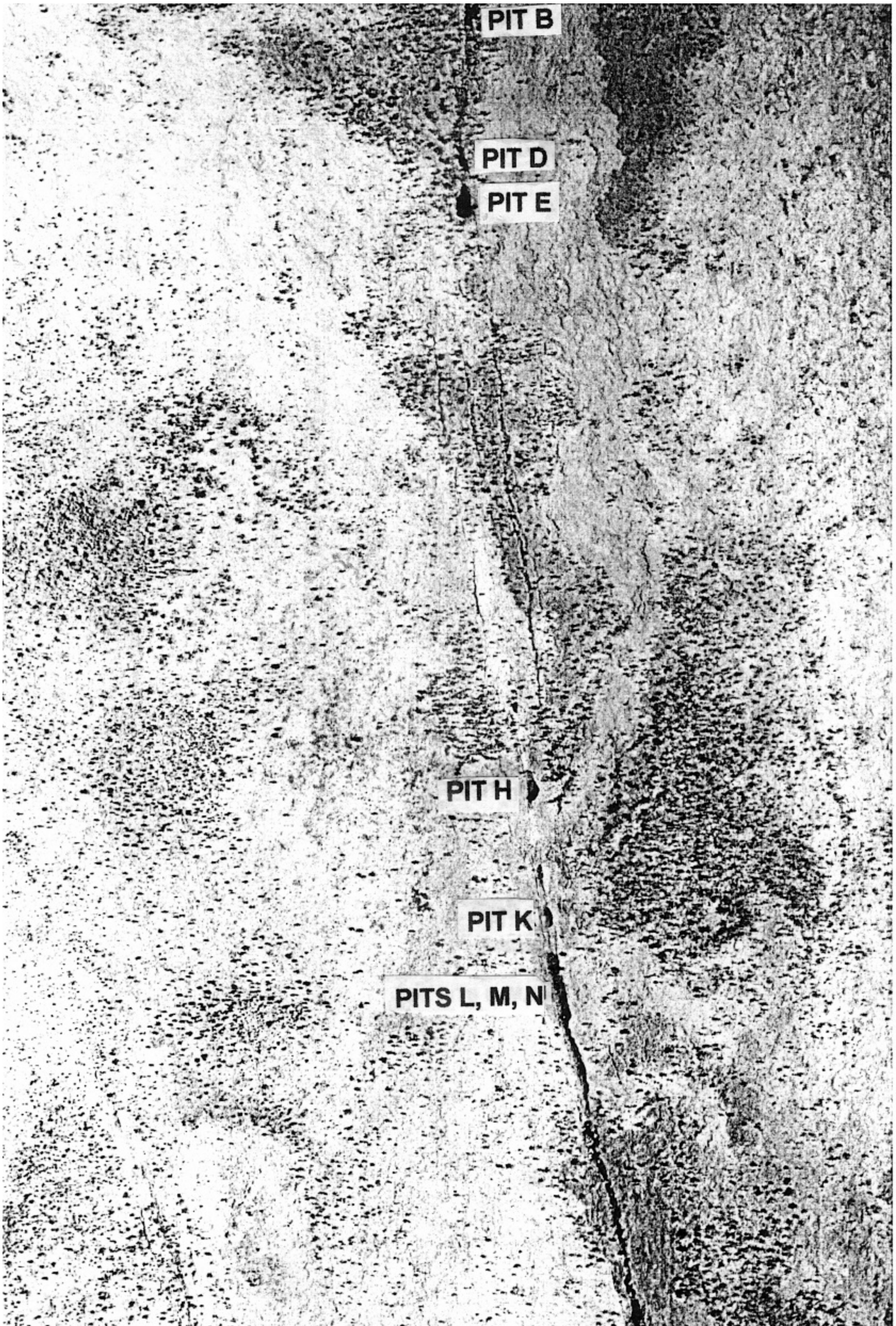

Figure 7. Crevice pseudokarst in a 2 km segment of the Southwest Rift Zone of Kilauea Volcano, Hawaii. Individual pits along the Great Rift are lettered from north to south; Pit H is near the center of the photo. It has been mapped to a depth of 186 m. Note that smaller en echelon crevices are mostly hidden by vegetation.

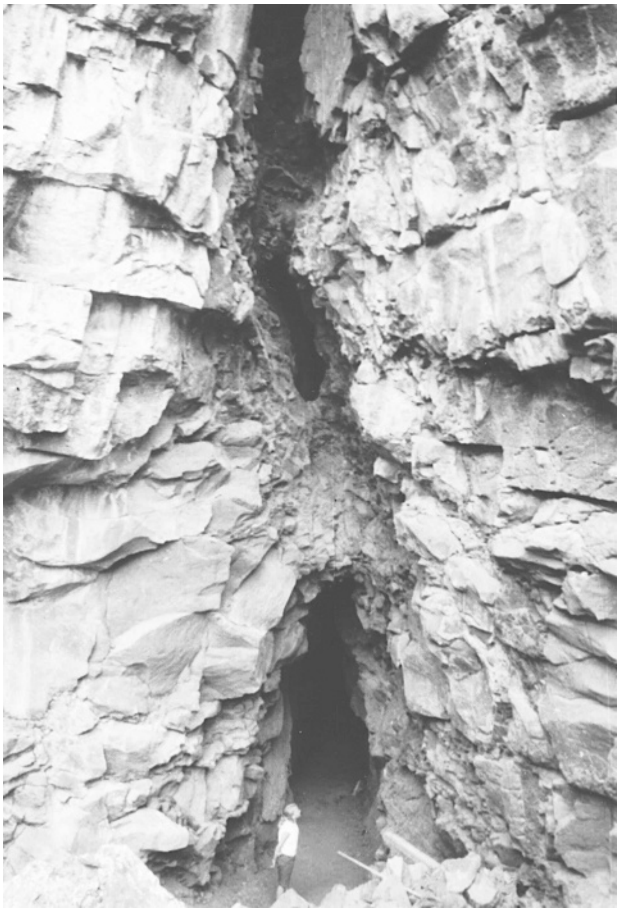

Figure 8. A short segment of the Great Rift, Idaho, seen from a large skylight. The flat is an artificial pathway constructed to permit visitor access.

before a lateral ash-cloud eruption covered its slump with several meters of slightly cohesive volcanic sand. The avalanche layer contained large and small fragments of fractured glaciere as well as shattered blocks of bedrock. Some were transported laterally for several kilometers in their original upright position. All was heated, but the degree of hydrothermal injection varied. Almost at once, melting and compaction began to generate crateriform and punched-out depressions varying widely in size.

The overlying ash cloud deposit underwent rapid erosion, with formation, enlargement and headward erosion of new gullies followed by coalescence of closed depressions and pond formation. During the first few months, vertical piping was prominent locally. As gullies enlarged, deepened and pirated their neighbors, parallel crevices formed in the pyroclastic ash cloud sand, elongating up-slope. Some were partially roofed by block slumping, and piping developed along their bases. More extensive roofing formed a few short-lived pyroclastic caves.

A 1 m layer of quicksand atop one temporary pond supported the weight of investigators, but did not withstand the impact of large rocks which sometimes broke loose and rolled down the steep slope of the closed depression. The resulting orifice revealed muddy water in a low cavern roofed by the quicksand layer.

Overall, this pseudokarst evolved rapidly. With each seasonal rain, the surface of the ponds rose disproportionately as the ash cloud deposit washed into them. Surface drainage developed, and all but the largest depressions disappeared within 15 years. After 25 years the area still could be recognized as pseudokarstic.

In southern Nevada and adjacent Utah, several small caves and pits have been identified in alluvium including Alluvium Cave. Some, but not all, are the result of piping.

Consequent Pseudokarst

Consequent pseudokarst is karst-like terrains resulting from action of natural processes on shallow mines, underground quarries and other subsurface works of man. Although the U.S. Geological Survey has studied many such occurrences, the term and the unifying concept were developed late in the 20th Century by Istvan Eszterhas of Hungary. Some of the affected areas contain extensive caverns formed by natural stoping, bounded on all sides by talus or by fracture surfaces. Their surface features tend to be rectilinear, and they commonly cause serious engineering problems. Underground drainage is minimal or absent.

The Future of Pseudokarst

Despite 20th Century progress in this rapidly emerging field, documentation and study of pseudokarst inevitably has lagged behind those of karst. Application of hard-learned calcareospeleological exploration techniques to some volcanic pseudokarst, however, has shown that many long-established techniques are easily modified to meet new conditions as needed (e.g., hyperthermal, hypothermal, hypoxic, and hypercarbic caves).

If this is to be man's century of breakout into space, speleologists everywhere need to stay alert to the great volume of relevant data now pouring back from Mars and beyond, and to volunteer our assistance in the interpretation of data already seen to demonstrate confusingly varied terrains. This is an area of progressively narrow specialization and we cannot expect planetary geologists, or even terrestrial geologists lacking in experience with various types of terrestrial pseudokarst, to recognize and properly utilize their extraterrestrial analogues. Already on Mars, what appears to be a typical crevice cave has been identified as a potentially habitable lava tube. Plans relying heavily on such misidentifications open the way to disaster.

Perhaps the first step should be breaking down the language barrier which still hinders definitive communication between central European pseudokarst specialists and those of the rest of the world. If necessary, travel to a series of international meetings on pseudokarst should be subsidized. The National Speleological Society and the

Figure 9. Landing created by wedging of rockfall, the Great Crack, Hawaii. Terrestrial caves of this type are unsuitable for human habitation.

Figure 10. Subsidence pseudokarst. This conical depression in the Spirit Lake pseudokarst (Mount St. Helens, Washington State) was photographed in an early stage of its evolution. A thin ash-cloud tephra deposit is still present on the flats formed on top of the landslide deposit containing the sinkhole.

International Union of Speleology should take the lead in such endeavors. The survival of man in space may depend on it.

Acknowledgements

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