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# A theological Study on the Depression Form & Closed small Hollows in Karst Landforms

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**Abstracts** : There are lots of depression forms and closed small hollows in the Karst landforms. For example, doline, uvalas, corrosion plains are belong to this case. In Karst surface it can be find that the gorges, meander caves, natural bridges, blind valleys, steepheads and dry valleys are well known landforms.

**Key word** : doline, cenotes, Karst window, Karst gulf, cockpits, uvalas, corrosion plains

## Ⅰ. Introduction

Karst is terrain with distinctive landforms and drainage arising from greater rock solubility in natural waters than elsewhere. This is a simple definition, and what does and does not necessarily follow from it requires some discussion. Solution is not always the most prevalent process in karst, nor is it necessarily the dominant one, but it does play a more important role here than in other kinds of landscape. Its most critical effect lies in the enlargement of underground voids, causing increased permeability of the rock. This leads to the progressive replacement of surface by underground drainage.

Nevertheless karst cannot be defined simply in terms of that replacement, because some kinds of karst (e.g. tower karst) have mainly surface drainage while other terrains, such as volcanic pumice country, may lack surface drainage from another cause and fail to develop further karst attributes.

Closde hollows in karst are created by karst processes, whether directly by corrosion or indirectly by subsidence and collapse into underground cavities created by dissolution. The main forms are dolines and uvalas, cenotes, and cockpits. There are also numerous atypical karst basins of various sizes which cannot be classified in any one of these categories.

Valleys take on special characteristics in karst, but these characteristics are accompanied or replaced to varying degrees by closde depressions, which identify the surface of karst most of all. Usually these are distinguishable from colsed depressions formed by other agents such as tectonism, vulcanicity, glaciers, periglacial action and wind. But when karst is subject to these other forces also, problems arise, especially when composite features result.

## Ⅱ. Closed small Hollows in Karst Surface

### 1. Dolines

Dolines are the most wide-spread karst form.

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They are to be found in every karst landscape, whether they appear as funnelshaped, bowlshaped, or as flat, dishand troughshaped dolines. In the Slavic languages dolina means a valley, but also small, closed karst hollows. The term was introduced into geomorphology by Austrian geologists. Dolines are defined as "simple, funnel, bowlor kettlshaped, closed karst cavities with under-ground drainage and a diameter which is greater than their depth" . Troughshaped should be added to this definition. To avoid confusion with dolina has been used exclusively for doline in Slovenic karst literature for several deeades.

The diameter of the doline varies between a few meters and 1000m, with a depth of up to 100m and the surface between 0.17㎡ and 159,200㎡.

A genetic classification differentiates between solution dolines, solution subsidence dolines, and collapse dolines. Solution dolines are formed when the limestone is dissolved away from under a soil covering by a widening of the interstices. Nicod (1967) found in the Provence that dolines in bare rock are not deepening any more, but that those under soil are today still continuing to develop. Rain is the most important factor but drifting snow effects additional corrosion until late in the spring, in the high mountains until summer. The deepening takes place because of, among other things, the widening of the interstices in the rock with resulting settling. Blocks and soil formations sink, too. Fine material, later also sand and stones, are washed away through the widened in interstices. If the drainage ways are widened enough in the over-lying, loose material, inner erosion results and funnels form on the surface. Williams (1969) calls this type an alluvial doline. Further developments in the underground bring about a settling of the rock and the loose material slides after. Thus the alluvial doline is genetically an intermediary type between the pure solution doline and the subsidence doline.

The subsidence doline is created by a slow downward movement of a mass while the collapse doline is formed by one rapid, usually single occurrence, caused by a cavity which lies near the surface. The collapse of the cavity's roof can open an entrance to a cave, e.g., at the well-known cave of St.Kanzian (Slovenia) through the Small and the Large Doline, and at the Grotta di Castella-na south of Bari (Italy). Deeply situated cavities gradually break through until finally the roof collapses. The famous collapse dolines of Imotski belong to this type. The Modro Jezero (Blue Lake) lies in a funnel doline which is 245m deep with steep, in places even vertical, walls. Weathering has made a funnel out of the original kettle form. The Crveno Jezero (Red Lake) lies in a 481m deep shaft which is only 200m in diameter. The facts that the ratio of its width to its depth is 2:5 and that the lake is filled by underground karst water hardly allow this form to be counted among normal collapse dolines. The Red Lake is a cenote.

The morphological classification is still today essentially according to Cvijić(1893): funnelshaped dolines, bowlshaped dolines, troughshaped dolines, kettle-shaped (shaft) dolines. Well-developed, funnelshaped dolines form in loose material or in slightly weathered rock, e.g., in thinly layered limestones. Bowlshaped dolines show a flat floor, trough shaped dolines have a concave one. Usually secondary dolines form in them; these are generally funnelshaped with rocky outcrops or large stones visible.

In thickly layered limestone denudation is slight; it is also only slightly susceptible to frost weathering; corrosion works vertically into the depths, and only a little hori-zontally. The result it forms with vertical walls, and irregular in their cross -section, also rounded: karren dolines, kettleshaped dolines. They are not collapse dolines. Already early there was a difference made between asym -metrical and symmetrical dolines, a morphogenetic division. Symmetrical dolines are round to roundedly elliptical; asymmetrical dolines are lopsidedly extended with vari-ously inclined slopes.

Asymmetry is caused by superficial water courses which end primarily in a swallowhole and develop into a form that can be morphographically called a doline. Watercourses can, however, rip up an existing doline. Structurally asymmetrical dolines form on inclined limestone banks.

There can also be climatic causes of asymmetry, e.g., when rain or snow are regularly brought in from one certain direction of the compass; e.g., in Central Europe from the west. Chabot (1927) mentions finding in French Jura asymmetrical dolines with steep inclines toward the north and east, which he assumes are caused by drifting snow. The south-exposed side of dolines with soils rich in humus is biologically more active because of the greater warmth; this causes a flattening process. Haserodt (1965) observed in the case of large dolines on the borders of frost-wenthered zones that the steepest and frequently bare rock slopes are exposed to the east and northeast. Sweeting (1972) mentions similar forms in th Permian limestone of Vaughan (UAS).

There is little to be found in literature concerning the inner structure of dolines. Aubert (1966) made a cross-section of an asym metrical solution doline in the Vallée de Joux (Swiss Jura), which is very complicated in its structure; it contains loose mate-rial from the Prewürm Age up to today and shows an open canal, 80㎝ in diameter be -neath. The author investigated numerous funnel-shaped dolines on the Glattalp (central Switzerland); they were usually small dolines in marly limestones of the Upper Malm, 2-10m in diameter and 0.5-2m in depth. Here before the Würm Period undergorund water courses developed with dimensions of up to 200㎝ × 20㎝. Digging in a broad trough-shaped doline in the silvan karst over Hölloch (central Switzerland), we found a small system of caves which led down into the depths; it could not be explored to the end because the passage became too narrow. The single branches of the system began in secondary dolines. Clay with limestone fragments formed the ceiling.

## 2. Cenotes

Cenotes are collapse dolines above a high karst water sufrace and reaching in to it; they show a diameter/depth relationship under. Their walls are vertical, occasionally over-hanging. Neighboring cenotes as a rule show the same high water level. This type is frequent in Yukatan but by no means limited to that peninsula.

Gerstenhauer (1968) explains the origin of the cenote by corrosion by mixing waters; water seeping in mixes with the karst water-body in the underground. Incasion (breakdown) can cause the bottom of the cenote to extend beyond the water level: the "dry cenote.

## 3. Karst Window and Karst Gulfs

Two other hollows offer a glimpse of underground karst water, on one hand the karst window, on th other karst gulf. These forms were first descibed and named by Mallot (1932) when he found them on the Mitchell Plains (USA). A karst window is a large funnelshaped doline, in the depths of which a short stretch of a cave river is visible. This type is found in Spring Mill State Park (USA). This karst window has a diameter of 130m and a depth of 17m.

The cave river is open for an extent of 70m, but an alluvial surface is missing (cf. Osinksi, 1935).

The karst gulf is created by the collapse of a broad cavity which is situated close to the surface. The fragments are transported away by corrosion, less by erosion. At the bottom of the gulf sandy-clayey sediments are deposited.

Later extensions follow when corrosion cuts back under the overhang and lateral breakdown occurs. There is no rela-tion to an uvala or a small polje.

The type's locality is the Wesley Chapel Gulf (USA).

## 4. Cockpits

Cockpits are a hollow form in the cone karst of the humid tropics. This climate does not exclude the possibility of the occurrence of normal dolines, too, when lithologi-cal conditions are suitable. In Jamaica cockpits and katst cones devlop in the pure crystalline White Limestone (Middle Eocene to Lower Eocene) but only normal dolines in the marly Yellow Limestone (Lower Middle Eocene). The contours of the cockpit are not rounded as is the case with dolines, but starshaped with indented sides, which indicates that cone formation is decisive factor.

## 5. Uvalas

Uvalas, also called karst troughs by Cvijić (1901) are the most controversial of the karst hollows. Cvijić (1901) defines them as "larger, broad-bottomed karst hollows with broken ground" which show "no even areas on the bottom". H.Lehmann (1970) defines uvalas as "elongated, sometimes twisted like a valley, but generally bowl-shaped basins in karst", but wrongly neglects to mention the uneven ground which often shows dolines. The ISU (International Speleological Union, 1973) took this into consideration in its definition, but otherwise holds mainly to the definition of Lehmann. Jennings (1971) and Sweeting (1972) give too narrow a definition of the uvala as a hollow form with an uneven floor, which is the product of two or more dolines that have grown together (compound dolines); this is the best definition of uvalas in plateau rogions (England, USA) but does not do justice to all those in folded areas, e.g., in the Dinaric region.

### 6. Corrosion Plains

Corrosion plains are widespread in Dinaric karst, occur, however, also on the dge of and inside conekarst regions. They are found in most poljes, but they are also not infrequently outside them: on the lower course of the Cetina and of the Krka (Yugoslavia). They are usually horizontal; older ones are later also either tectonically bent, lifted, or cut up by later processes of corrasion.

They spread out fight across the tectonic structures in the limestone.

Kayser (1973) differentiates between marginal karst plains and polje floors. Here the question will be left open as to whether other corrosion plains within the karst should be explained as marginal karst plains — because of their wide expanse they also encounter unkarstifiable rocks — or as parts of a polje which was later split open, or even as parts of a river polje in the sense of Kayser (1934).

Gams (1965) explains the creation of such plains by accelerated corrosion in flooded areas, whereby the soils with their biogenic CO2 supply the water with the necessary CO2. Roglić (1957) explains the extensoin of the polje by a growth of the corrosion plain from the boundary of the rock into the limestone; this is due to the action of the polje waters which on the one hand make the permeable underground watertight, on the other hand, however, dissolve the limestone laterally around the ordering ponors. This, however, does not explain the striking constancy of height over relatively large distances. According to Rathjens (1954) Dinaric corrosion plains are the forms of an earlier age when the climate was warmer and wet seasons alternated with dry. Accord-ing to Kayser (1934) they should continue to develop today; this can be observed on the lower Neretva and on the Skadersko Jezero (Skutari Lake). Pfeffer (1973, 1975) points out that in humid climates corrosion plains develop only at the level of inunda-tion, but that the morphodynamics of dry climates also cause such plains in karst.

## Ⅲ. Depressions form in Karst Surface

### 1. Gorges

Although gorges are found in practically all rocks, they are more frequent and bolder in karst, other factors such as general relief and climate being equal. The Grandes Causses of central France are sliced into separate plateaus by the gorges of the Tarn, Jonte, Dourbie and Lot, 300-500m deep. In young, folded mountain ranges, much larger gorges occur, such as the Verdon Gorge in th southern French Alps, the Vicos Gorge, 1000m deep but only 1500m across, which is the 'Grand Canyon' of Greece, the Nahanni Gorge in north-western Canada and the Strickland Gorge in New Guinea. However, they are numerous also in limited available relief.

Narrow canyons form, as with Bungonia Gorge, which has nearly vertical walls up to 300m high. But that steepness is often retained with meagre relief. Thus the archaeologically famous Creswell Caves in northern England are developed in cliffs less than 20m high on both sides of a broad floodplain.

Allogenic drainage is dominantly responsible for karst gorge formation. However, the essential mechanism in this prevalence of gorges in karst is the failure of slope processes to flare back the vlley sides. Marked infiltration and reduced runoff minimize slope wash and many kinds of mass movement that tend to widen valleys and moderate their steepness. River incision, on the other hand, is favoured by the readiness with which the bedrock river channels may be dissolved and abraded. Swirihole action, both mechanical and chemical, is particularly effective in karst. Dissolved load is also more easily transported than clastic load. Flatter longitudinal profiles result, and so rivers can run through gorges from their entry into karst to their leaving it.

The sides of the gorges are, of course, not entirely in cliff; a frequent element to be found is a uniform bedrock slope fo 25-35° with only thin and patchy cobers of talus. These 'Richter slopes of denudation' are more common in karst than elsewhere because of readier removal by solution of talus falling on them from above.

Cave roof collapse has frequently been offered as an explanation of gorges in karst. This certainly applies in some cases, where sections of cave roof survive between unroofed sections, as with the Rak Valley in Slovenia and along the Oparara River, near Karamea, NZ, where three natural bridges come in close succession. However, it has been called upon in many places with no supporting evidence and, indeed, even where there is contradiction in the shape of surface rejuvenation forms along the Cheddar Gorge in Mendip, England (Ford and Stanton 1968). There is the risk of extending too far the significance of a natural bridge, as Sweeting (1972a) has warned for the famous case of Gordale Beek in Craven, England. A collapsed cave may just be one sector of a gorge formed mainly by surface processes.

Although dolomite can stand up in great cliffs, as witness the famous peaks of the Dolomites in the European Alps, this rock usually forms V-shaped valleys rather than the vertically walled gorges favoured by limestone in comparable circumstances. There is also greater readiness to break up into 'ruiniform' relief , with castellated rors, etc.

## 2. Meander Caves

A contributing factor in maintaining the steepness of valley sides in karst is effective lateral action by rivers. Corrasional undercutting of valley sides encumbers a river with debris, whereas corrosion does so not directly but by rockfall. Rockfall from undercutting is alsomore readily removed because of its liability to solution as well as to abrasion. In addition, the comparative softeness of calcite favours attrition.

Consequently meander caves are typically karst forms, though their frequency must mot be exaggerated. A good example is provided by Verandah Cave, Borenore, NSW, which is at the base of an ingrown meander cliff. The Verandah itself is a remnant of a higher abandoned meander cave corresponding to a rock terrace upstream.

## 3. Natural Bridges

Natural bridges are more common in karst valleys than in others. Cleland (1910) distonguished between a natural bridge, through which a river runs or has run, and a natural arch, where the span has never bridged a river but perforates spurs as a consequence of weathering, e.g. La Grigna, Italy. When a feature should be called a bridge or regarded simply as a cave is bound to be arbitrary. As good a criterion as any is that daylight reaches through a bridge. The larger and straighter the penetrating passage, the greater the length that can be lit from outside. On this basis the 180m long Arch Cave at Abercrombie, NSW, is porbably close to the limit. Where a stream crosses a narrow band of limestone, a cave may become nothing more than a bridge. Steeply dipping beds favour such narrowness of outcrop as at Jenolan, NSW: here the Grand Arch is about 140m long in an outcrop only 180m wide. Its greatest span is 50m and its maximum height 20m above Harry Creek flowing through it.

Other bridges are surviving parts of much longer cave roofs, as with the Rak Valley mentioned above. Some natural bridges of this type are associated with underground river capture, with the valley below the bridge more deeply enternched by the work of the capturing stream. This is thought to be the situation at Natural Bridge, Cedar Creek, near Lexington, and at Natural Tunnel on Stock Creek near Clinchport, both in Virginia .

Self-capture is a common cause of natural bridges. Menader caves on one or both sides of a meander spur can breach the limestone through edge plane action of the whole stream, but generally water escaping from the river by solution along joints or bedding planes will have pierced the spur before that. London Bridge, Burra Creek, NSW, provides a good example of a bridge formed this way. Here a meander spur includes a narrow band of nearly vertical limestone. The long bend was cut off by cave development across the neck of the spur where the limestone lies. An alluvial fan has partly filled the old meander and its construction may have been a final trigger to abandonment of the surface course.

Bridges also develop without meandering by self-capture at rejuvenation heads. Where waterfalls cascade down the steep drop in the river profile, joints may open up behind and engulf more and more of the flow to leave a span of rock over the degenerating fall. Cleland (1910) suggested this was involved at the Natural Bridge near Lexington.

## 4. Blind Valleys

Eventually a sinking stream cuts its bed so far below the threshold that it always goes underground and never flows beyond. Thus a blind valley is produced, closed off at its downstream end. The reversed slope may be only a few metres high or may range into hundreds of metres. The larger the disappearing stream the more likely is it to enter an open cave. The blind valley closes off only 45m within the limestone and the stream enters a cave at the foot of crags in the 15m counterslope. Beyond, a valley about 8m deep is interrupted by small dolines; this is the much modified former onward course of the stream.

Sometimes blind valleys possess a series of closed depressions into which the stream spills successively as it banks up in flood, each one providing entry into the underground conduit.

Temporary ponds or small lakes form in this way as they do also with half-blind valleys. With a high threshold, a vertical sequence of entries may be left by a deepening of the blind valley.

How far bline valleys reach into the karst and how ig they become depend on various factors. Studying some large blind valleys in the classical karst of Slovenia, Gams (1962) found that their form was related to the carbonate content of the stream waters where they entered the karst. With high concentrations there, the blind valleys are narrow and short, whereas where they are low, long and wide, blind valleys are narrow and short, whereas where they are low, long and wide, blind valleys are found.

At Yarrangobilly, NSW, the dimensions of blind valleys were compared with those of their catchments outside the limestone to test the hypothesis that the bigger the catchment, the bigger would be the blind valley that resulted. In fact, only a partial explanation was provided in this way because the time since under-ground capture varied. The older a blind valley, the larger it is likely to be.

The shape of blind valleys will also vary with the nature of the alluvium accumulating in them. If this is impervious, it will tend to seal off the floor and favour widening by lateral erosion of the sides. With pervious alluvium, as with much Pleistocene cold climate gravel in the Yugoslavian karst, solution can still go on beneath the openwork fill, continuing to deepen the valley without widening it much.

## 5. Steepheads

Springs of both exsurgence and resurgence type are frequently found at the heads of valleys, which begin very abruptly and are steepwalled, sometimes like gorges. They are ususlly short valleys in the margins of plateaus or in the flanks of mountain ranges. The Fontaine de Vaucluse in Provence arises beneath a 200m cliff at the head of such a valley; this is implied in the origin of the nameval clos. In several languages the popular name for these cul-de-sacs is 'World's End', but in English the American term steephead is becoming customary for them in scientific writing. A distinction is sometimes made between steepheads incised to an impervious basement and pocket valleys where the floor of the valley is still within the karst outcrop.

These features may be due to spring sapping. A spring undermines the cliff or slope above it; rock and soil gravitate into it and are removed by the stream. In this way there is headward retreat of the valley, an evolution implied in the French term for them. However, the gorge may be due to collapse of substantial lengths of cave roof, which has happened in several sections united later by further collapse. Natural bridges may survive to prove this second mode of origin, but if the valley formed a long time ago, such distinguishing evidence may now be lacking.

Whatever the manner of formation of a steephead, when the waters emerging are autogenic, both stream and valley are 'old at birth

### 6. Dry Valleys

Dry valleys lack stream channels in their floors (plate 18). Defined thus simply, they are not confined to karst. In normal fluvial relief, streams often have short dry valleys at their heads and their minor tributary valleys may be enrirely of this nature. In them, surface flow is not sufficiently large or frequent to gather into linear threads capable of cutting a channel. Longer and branching dry valleys form on pervious rocks such as sandstone and pumice, but dry valleys are most characteristic in karst.

Some of the most spectacular dry valleys in karst are the easiest to explain. Allogenic river valleys often continue through karst beyond their sinking points in dry valleys. In the Istrian Plateau, three rivers have eroded wide valleys in impervious rocks in which they rise and then drain south-west into limestone . Two of them, the Mirna and Rasa, cross the karst to reach the sea along canyons. Between them, a third river sinks at the limestone but its former course is continued along the Pazinksi Potok, a dry valley of canyon form.

## Ⅳ. Conclusion

The multiplicity of possible karren forms makes a morphological system endless, while a genetic one allows a meaningful collection. The manner in which they are moistened and the conditions of drainage of the corroding water are fundamental to it. Therefore a differentiation is made between karren forms which are created by free, unhindered water flowing off over bare limestone surfaces, those which are caused by a patchy covering of soil, and ghose which develop beneath a closed covering of soil. These are the basic forms. They change in appearance when conditions change, e.g., when over-grown: subsequent forms. In addition to single forms form complexes and groups of form complexes can be differentiated.

There are several reasons for the existence of karst Depressions and Hollows on the surface.

Dolines are the most wide- spread katst form. They are to be found in every karst land scape.

Cenotes are collapse dolines above a hish katst water surface. They show a diameter/depth relationship under. Katst window and karst Gulfs offer a glimpse of unterground karst water, on one hand the karst window. Cockpits afe a hollow form in the cone karst of the humid tropics. Corrosion plains are widespread in Dinaric karst and inside cone karst regions. gorges are found in practially all rocks. Meander caves are typically karst forms and must not be exaggerated. natural briges are common in karst valleys than in others. Blind valley is produced down stream end. Steepheads frequently found at the heads of valleys. Dry valleys lack stream channels in their floor.

Frequently rivers flow only a little way into the karst and end: blind valleys.

In Indiana and Kentucky they haver significant names like Lost River and Sinking Creek; their valleys are only few meters deep, and dry valleys interlaced with dolines form their continuation (Mallot, 1939, 1945; Powell, 1965). Also autochthonous karst valleys which still end in the karst count as blind valleys. Dry valleys, which lead on from blind valleys to a higher level, bear witness to an earlier active phase and to successive under-gorund tapping. Pocket valleys lead the water of larger karst springs (river source) away out of the karst. They are often dalled vout monde. They are frequently explained as collapsed underground water-courses, thus Malham Cove in the North Pennines (GB, Hudson et al., 1933).

A geographical division shows on one hand a zone of poljes in subtropical climates with alternating wet and dry seasons, on the other hand such a zone in the humid trop-ics where the poljis are mainly bound to cone-karst regions.

Thus they show a consid-erable dependence on climate (climate-morphology.)

It is, however, striking that in warmly temperate North America there exists till now but one known polje, Grassy Cove, which was first taken to be a huge uvala (Lane, 1952). It lies on the subtropical, slightly folded Cunberland Plateau in Tenessee. Poljes are amassed around the Medi-terranean Sea, with concentrations of them in the Dinaric, Greek region and in th mid-Appennines, as well as in the Taurus Mountains (Louis, 1956) in Anatolia. In southern France there are a few examples, e.g., the Plan de Canjeurs (Nicod, 1969); in Spain they are even rarer; they can be found cccasionally in Morocco, in Mid-Atlas, e.g., the Daja Chiker (Ek and Mathieu, 1964) and the Polje of Augelmane Azigza on the Causse d'Ajdir (Martin, 1965).

The poljes in the cone-karst regions of the humid tropics, the interior valleys enjoy a special position. They frequently occur as marginal poljes, e.g., in Cuba on the Sierra de los Organos (H. Lehmann et al., 1956) or in Puerto Ricco (Monroe, 1960, 1976). In Jamaica a rare form lies in the midst of the cockpit karst, the tectonic polje of Lludas Vale (Sweeting, 1958). In the cone-karst regions of southeastern Asia they are relatively rare (Balazs, 1968; von Wissmann, 1954; H. Lehmann, 1936).

## ⟨References⟩

Allen, J.R.L.: On the origin of cave flutes and scallops by the enlargement of inhomogeneities. Atti Rass.spelcol. Ital. 3-19 (1972)

Allen, J.R.L.: Transverse erosional marks of mud and rock: Their physical basis and geological significance. In: Sedimentary Geology, Intern. J. applied regional sedimentology, Elsevier, Amsterdam, 1971

American Geological Institute: Dictionary of geological terms. Dolphin Reference Book C 360 (1962)

Ford. D.C.: Geologic structures and theories of limestone cavern genesis. Brit. Speleol. Assoc., Settle, Yorkshire, 35-45 (1970)

Ford. D.C.: Geologic structure and a new explanation of limestone cavern genesis. Trans. Cave Res. Group, G.B. 13, 81-94 (1971)

Ford. D.C.: Castleguard Cave, an alpine cave in the Canadian Rockies. Stud. Speleol. 2/7-8, 299-310 (1975)

Ford. D.C., Harmon, R.s., et al.: Geohydrologic and thermometric observations in the vicinity of the Columbia Icefield, Alberta and British Columbia, Canada. J. Glaciol. 16, No. 74, 129-230 (1976)

Ford. D.C., Schwarcz, H.P.: Radiometric age studies of speleothem. Geol. Surv. Can., Paper 76-1B (1976)

Ford. T.D.: Structures in limestone affecting the initiation of caves. Trans. Cave Res. Group, G.B. 13/2, 65-71 (1971)

Frank, R.: The clastic sediments of Douglas Cave, Stuart Town, N.S. Wales. Helictite 7, 3-13 (1969)

Frank, R.: The effect of non-climatic factors on flowstone deposition. Proc. 6th Int. Congr. Speleol. I, 413-417 (1975)

Groom, G.E., Williams, V.: The solution of limestone in South Wales. Geogr. J. 131, 37-41 (1965)

Halliday, W.R.: Changing concepts of speleogenesis. Natl. Speleol. Soc. Bull. 22, 23-28 (1960)

Halliday, W.R.: Caves of California. Seattle: Selbstverlag (1962)

Harmon, R.S., Thompson, P., et al.: Uranium-series dating of speleothems. Natl. Speleol. Soc. Bull. 37, 21-33 (1975)

Harned, H.S., Davis, R.: The ionisation constant of carbonic acid in water. . . Am. Chem. Soc. J. 65, 2030-2037 (1943)

Harned, H.S., Scholes, S.R.: The ionisation constant of HCO3- from 0℃ to 50℃. Am. Chem. Soc. J. 63, 1706-1709 (1941)

Harned, H.S., Owen, B.B.: The physical chemistry of electrolytic solutions. 3rd ed., New York: Reinhold 1958

Herak, M., Stringfield, V.T.: Karst; Imporatant Karst Regions of the Northern Hemisphere. London: Elsevier 1972

Hicks, F.L.: Formation and mineralogy of stalactites and stalagmites. Natl. Speleol. Soc. Bull. 11, 63-72 (1950)

Hill, C.A.: Cave minerals. Natl. Speleol. Soc. Huntsville AL, USA (1976)

Hjulström, F.: Studies on the morphological activities of rivers. Bull. Geol. Inst. Uppsala 25, 221-527 (1935)

Holland, H.D., Kirsipu, T.V., et al.: Chemical evolution of cave waters. J. Geol. 72, 36-67 (1964)

Howard, A.D.: The development of karst features. Natl. Speleol. Soc. Bull. 25, 45-65 (1963)

Howard, A.D.: Verification of the "Mischungskorrosion " effect. "Cave notes" 8/2, Dept. Geogr. Johns Hopkins Univ., Balitmore MD, 1966, 9-12

Hubbert, M.K.: The theory of ground water motion. J. Geol. 48, 785-944 (1940)

Jennings, J.N.: Syngenetic karst in Australia. In: Contributions to the study of karst. Dept. Geogr. Publ. G/5, Austral. Natl. Univ., Canberra 1968, 41-110