The Green Plants growing in Akiyoshi-dô Cave, Southwestern Japan

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The Green Plants growing in Akiyoshi-dô Cave, Southwestern Japan[1]

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Akiyoshi-dai is the most extensive karstic plateau in the Japanese Islands. It occupies the northeastern half of the Akiyoshi limestone area and is excavated by many caves and potholes, among which is found the vastest one of the Japanese limestone caves. It is called either "Akiyoshi-dô" or "Shûhô-dô". Besides the remarkable development in scale, this cavern is bestowed with a variety of cave formations. It has long been commercialized, and is so well known in Japan that the name "Shûhô-dô" attains to have become a substitute of 'shônyû-dô' that means 'limestone caves' in Japanese.

On his collecting trip in the Far East made in 1925, the late Prof. F. SILVESTRI happened to visit the cavern, which was then called "Taki-ana", and investigated the cave animals for the first time. A new troglophilous opilionine was then described from his collection[2]. Two years later of SILVESTRI's visit, Prof. M. UÉNO investigated the aquatic fauna of the same cavern, finding three species of cave-dwelling crustaceans[3]. Since that time, however, no successor had appeared till the times just before the outbreak of the World War II, when three biologists[4] worked independently on the cave fauna.

After the War, the researches for cave animals have rapidly progressed in Japan, and the animals inhabiting Akiyoshi-dô Cave have been investigated repeatedly. Considerable efforts have been directed by UÉNO, one of the authors, to clarify the fauna. Systematic surveys were also carried out in 1956 and 1957 by the Spelaeological Society of Japan. The more the knowledges have become enlarged, however,

1) Contribution No. 27 from the Spelaeological Society of Japan.
2) *Strisilvea cavicola* ROEWER, 1927, p. 197.
3) UÉNO, M., 1927.
4) Dr. T. HABE, Messrs. H. TORII and Y. IKEDA.

the more the investigators have been puzzled with the excessive abundance of trogloxenes found in Akiyoshi-dô Cave. The matter is apparent on the lists of animals obtained in the cavern, compiled by two different authors[5]. Yet, the actual number of the species is much larger than those appeared on these lists concerning the trogloxenous animals hitherto found in Akiyoshi-dô Cave. According to the present authors' own knowledges, they are so numerous in the cavern as to be impossible even to compile a tentative list of them. It is obvious that such a phenomenon could not be resulted from one or two simple causes. It may have arisen from a co-operation of some peculiar environmental factors, e. g., that the cavern has long been illuminated for tourists, that it has a large entrance, through which the sunlight penetrates into the cavern to a considerable extent, that there are many potholes connecting the cavern with the karstic surface, and that the stream which runs through the cavern is not only the underground water of phreatic zone but is an assemblage of the surface waters. There is one more remarkable factor in the cavern, which seems to play an attractor for epigean animals. It is the presence of green plants.

Naturally, no chlorophyll-bearing plant grows in the total darkness within caves. Fungi are frequently found in the depths, growing on rotten boards or logs, and furnish nutriment to springtails and snails. They are, however, not identified as yet. The subject of the present paper is to show the presence in Akiyoshi-dô Cave of the colonies of green plants under natural and artificial lights. Such an attempt may be of some value for the future studies on the speo-ecology in the cavern.

Environmental Conditions in the Cavern

In Akiyoshi-dô Cave, the cave walls on which the plants are found are composed of limestone at every station. This is rather exceptional, because, in Japan, massive limestones are usually interbedded with the other rocks (e.g. chert), which are frequently exposed on cave walls. It is, however, difficult to consider the vegetation to be restricted to limestone. Several papers have hitherto been appeared dealing with the Japanese limestone plants, coming usually to a result that the so-called limestone plants are really not alkali-philous but merely resistible to drought. Owing to the humid climate, genuine limestone flora is not so prominent in Japan as in Europe.

The climatic conditions inside the cavern are, of course, greatly different from those of the outside. The humidity of the air is extremely high, above 90 per cent even at the twilight zone (ISHIKAWA, 1957, p. 32). The temperature is not only low (below 16°C), but always low. There is no current of the air in many places in the cave. Further, they are remarkably constant, especially in the depth. Such a peculiar environment allows only some particular species of plants to grow in the cave.

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5) TORII, 1956, pp. 423-424; ISHIKAWA, 1957, p. 33.

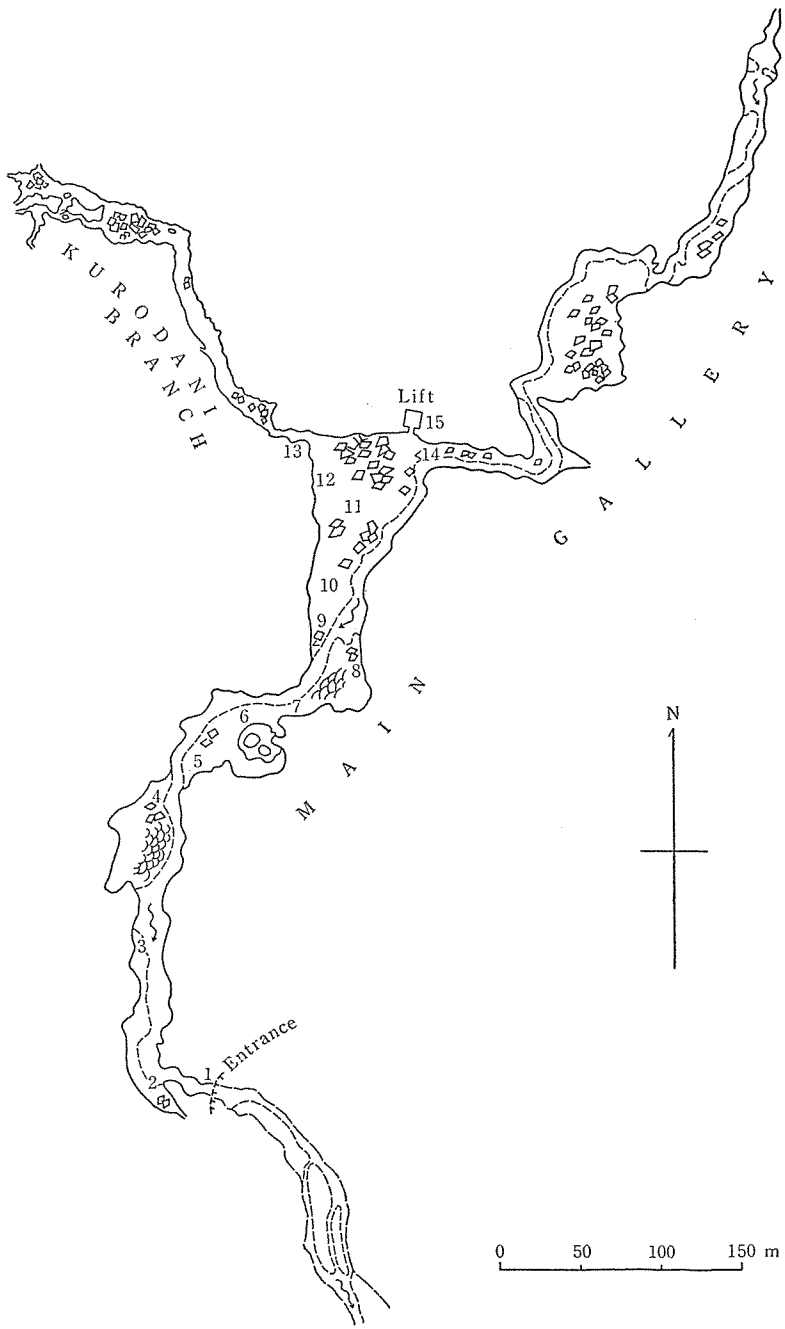

Fig. 1. Sketch map of Akiyoshi-dô Cave (adopted from ETO, partly modified by YAMAUTI, 1957); the numbers 1–15 indicate the stations investigated (*cf.* pp. 318–319).

Beyond these features, extreme shortage of light gives an important and vital effect on the formation of flora. Artificial lights introduced in the cave are not comparable with the natural daylight in their efficiency, i. e. in the intensity and the quantity of light, in the wave-lengths, in the duration of illumination, and so on. There are two kinds of vegetations in Akiyoshi-dô Cave: that growing at the twilight zone under the faint daylight and that growing under the artificial lights installed for tourists. The latter is usually small and stunted, but sometimes attains to a full growth or makes thick carpets. Successive data are unfortunately not available for the formation of such vegetations. However, it may not be useless to give here a brief history of the installation of electric lights.

The first attempt to illuminate the cavern was made in October, 1925, with the installation of incandescent electric lamps. Since then, the illumination of this sort has been increased and improved. It makes a main source of light even at present. In December, 1956, several fluorescent lamps were installed in company with the establishment of a lift. The light thrown from these lamps is, however, so faint that no vegetation can usually be detected around them. More recently, in July of 1957, a dozen of mercury lamps were provided at the important places. The cavern is now equipped with three kinds of artificial lights, of which the effects upon the development of vegetation will be given on the following pages.

Green Plants in the Cavern

The plants inhabiting Akiyoshi-dô Cave were collected by the authors during their recent trip made in June and July, 1959. They are listed below according to respective stations. All the specimens examined are preserved in the herbarium of the University of Kyoto.

Station 1. Threshold (daylight).

Several species of ferns and bryophytes. Lichens and climbing seed plants are also seen.

Station 2. Rokujizô (incandescent lamp, mercury lamp and faint glimmer of the daylight).

Pteris multifida POIR.	4572[6]
Hypodematium fauriei (KODAMA) TAGAWA	4570
Cyrtomium fortunei J. SM.	4571
Asplenium varians WALL.	4573
Brachythecium buchanani (HOOK.) JAEG.	4569
Fissidens nagasakinus BESCH.	4568

Algae

Station 3. Nagafuchi (incandescent lamp).

Algae

Station 4. Hyakumaizara (mercury lamp).

Algae

Station 5. Hironiwa (incandescent lamp).

Algae

6) The numbers on this list indicate IWATSUKI's field numbers of the specimens.

Station 6. Kabocha-iwa (incandescent lamp).
Cyrtomium fortunei J. SM. 4575
Fissidens nagasakinus BESCH. 4574
Algae
Station 7. Chirimen-iwa (mercury lamp).
Algae
Station 8. Chimachida (incandescent lamp).
Pteris multifida POIR. 4578
Asplenium sarelii HOOK. 4577
Rhyncostegium sp.[7] 4576
Algae
Station 9. Kasazukushi (mercury lamp).
Algae
Station 10. Karataki (incandescent lamp).
Algae
Station 11. Senjôjiki (mercury lamp).
Algae
Station 12. Iwayakannon (incandescent lamp).
Fissidens nagasakinus BESCH. 4579
Algae
Station 13. Sarusuberi (incandescent lamp).
Pteris multifida POIR. 4583
Cyrtomium fortunei J. SM. 4582
Asplenium sarelii HOOK. 4584
Brachythecium buchanani (HOOK.) JAEG. 4580
Fissidens nagasakinus BESCH. 4581
Algae
Station 14. Eastern foot of Senjôjiki (mercury lamp).
Algae
Station 15. Lift (fluorescent lamp).
Algae

These plants were, no doubt, introduced into the cave after the artificial illuminations were installed. Their spores might have been swept in with the streams or brought in by human agencies, and might have settled there. They are usually different from the normal ones due to the peculiar environmental conditions. They are small and stunted in many cases, and are always sterile. These worse conditions make the identification much difficult.

Seed Plants:—Seed plants are found only at the threshold and wholly unknown at the dark zone. This strange phenomenon may be attributed to various causes: that the spores of mosses and ferns might have larger abilities of dispersion than the seeds of spermatophytes; that all the seed plants hitherto introduced into the cave might not be able to grow, because the minimum quantity of their light requirement exceeded the given light; that the seeds carried in might have missed

7) Refer to the paragraph of the bryophytes.

their chance, for some reason, to germinate normally; or that some of the climatic or the other factors might have been unsuitable for the survival of them. Any of these explanations, however, seems not to be satisfactory. To analyse the problem, it may be helpful to know what species of seed plants would settle down for the first and what species would follow the pioneer.

Pteridophytes:—No fern allies were collected. All the pteridophytes growing in the cavern are leptosporangiate ferns, as seen below:

Pteris multifida POIR.
Hypodematium fauriei (KODAMA) TAGAWA
Cyrtomium fortunei J. SM.
Asplenium sarelii HOOK.
A. varians WALL.

Of these species, *Hypodematium fauriei* was found only on the walls near the entrance, where there reached the faint glimmer of the daylight. This species is widely spread over the warm regions of Japan and Korea, and is usually known growing on dry limestone outcrops exposed to the sun. It is also taken on the cliffs in front of the entrance of Akiyoshi-dô Cave. At the present knowledge of the authors, it is difficult to understand why the species can not penetrate into the depth of the cave.

In the epigean habitats around the entrance, the genus *Cyrtomium* is represented by two species, including two varieties, i. e. *C. falcatum*, *C. fortunei* var. *fortunei*, *C. fortunei* var. *clivicolum* and *C. fortunei* var. *intermedium*. The cave specimens of *Cyrtomium* are easily identified as *C. fortunei*, because, in those specimens, the margin of pinnae is dentate near the apex. Closer determination is, however, impossible, as the plants are stunted and reasonably sterile. All the species belonging to the genus *Cyrtomium* are known to be of apogamous reproduction. This seems to be advantageous to the subterranean dispersal. *C. fortunei* is the most dominant species in the cavern and is always in good condition.

Bryophytes:—Hepaticae was entirely absent at the dark zone and was found only at the threshold. Three species of mosses were known in the depth. They were identified through the courtesy of Mr. T. NAKAJIMA as listed below:

Fissidens nagasakinus BESCH.
Brachythecium buchanani (HOOK.) JAEG.
Rhynchostegium pallidifolium (MITT.) JAEG.?

Mr. NAKAJIMA kindly gave the authors a note on the third species, in which he stated as follows: The Akiyoshi-dô specimen resembles the members of *Eurhynchium* in its general aspect and in the presence of small projections at the apices of costae, but is different from the latter in the shape of areolation and in the form of the apices of leaves. It agrees with characteristics of *Rhynchostegium* in some important features, and seems to be a variant of *R. pallidifolium*, which has suffered from the influence of peculiar cave environment.

Contrary to the supposition widely prevalent, mosses are not so common in the cavern as ferns, especially as the prothallia of the latter. The commonest among the cited three species is *Fissidens nagasakinus*, which is usually growing on the wet cave walls fed by trickling water and forms at the station 12 a considerably thick carpet.

Thalophytes:—In this paper, the cormophytes are mainly dealt with, for the authors' present interest is focused to the effect of artificial illuminations upon the formation of green vegetations. Some algae were collected around the electric lamps but yet undetermined. As regards the cave flora of lower plants, especially of fungi which can survive in the total darkness, close investigations should be required by the botanists of that field. Such troglobiontic plants must have direct relations with troglobiontic animals from the ecological point of view.

Animals depending on the Introduced Flora

Up to the recent times, nothing has been made to clarify the relations between the cave-dwelling animals and the introduced plants. The effect of illuminations upon the troglobiontic animals has been observed only from its destructive aspect. This is terribly true regarding many groups of cave animals. Troglobiontic beetles of the subfamily Trechinae, for example, are rapidly destroyed by the installation of artificial lights. There is, however, a few groups of animals, which do not suffer from the effect of artificial lights but can survive normally taking the introduced plants as their nutriment. Unfortunately, the accurate data are inadequate to show the phenomenon in relief. The authors will give here an example of such a case.

At the station 13, many individuals of a minute troglobiontic snail, *Cavernacmella kuzuuensis* (SUZUKI), are found on the wet stalagmitic wall (HABE, 1942, pp. 28–29). Troglobiontic as it is, this species can safely survive under the artificial light among the introduced vegetations. It usually feeds on algae, which has been found from its alimentary canal.

Further, a troglophilous fly, *Exechia* sp. is usually found at the station 2, and a harpacticoid copepod, *Bryocamptus zschokkei* (SCHMEIL) is taken at the station 12 in the carpet of *Fissidens nagasakinus*.

Summary

The occurrence of green plants is reported from the dark zone of Akiyoshi-dô Cave. Total eight species of cormophytes are found under the artificial illuminations installed for tourists. Five of them are leptosporangiate ferns and the other three are mosses. Of these species, *Cyrtomium fortunei* and *Fissidens nagasakinus* are dominant and sometimes attain to a full growth. The establishment of these vegetations seems to have ecological significance to the biospeology. Several examples are given towards the relations between the introduced plants and the cave animals.

In closing, the authors wish to express their hearty thanks to the authorities of the town of Shûhô-chô, to Mr. Ichiro ETO and his staff of Akiyoshi-dai Science Museum as well as to Mr. Seiu ÔBA and his family. Their kind aid rendered during the trip enabled the authors to make full investigations possible. The authors' deep gratitude is also due to Mr. Tokuichiro NAKAJIMA of Kishiwada High School, who kindly takes labour of identifying the specimens of mosses.

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