USE OF THERMOPHILIC ALGAE IN GEOTHERMAL EXPLORATION PROGRAMS

Thomas Flynn, Dennis T. Trexler,
and Brian A. Koenig

Nevada Bureau of Mines and Geology
University of Nevada, Reno 89557

ABSTRACT

An aerial survey technique for the exploration of hot springs in areas of limited access was tested at nine sites in northern Nevada. The technique is based on the properties of thermophilic blue-green algal species, which are common throughout non-acid hot springs in the western United States. Red- and green-colored algal growth patterns, which depend on water temperature and pH, have been recognized in color aerial photographs taken at an elevation of 4000 ft. above terraine. The successful application of this technique may enhance future geothermal exploration programs in areas of limited access.

INTRODUCTION

In July, 1978, the Nevada Bureau of Mines and Geology began field work on a U. S. Department of Energy, Division of Geothermal Energy funded State Geothermal Assessment program (contract number ET-78-S-08-1556). The field work consisted of providing physical and chemical data for thermal springs and wells for which no data were available, and ascertaining the validity of previously obtained, but conflicting, data.

Unfortunately, many areas in Nevada remain unsurveyed and vehicular accessibility is often precluded by a variety of natural and man-made obstacles. Of the 81 sites selected for data verification, 10 sites were completely inaccessible and 33 sites had water temperatures of 20°C or less.

During the course of the field work, distinctively red- and green-colored subaqueous thermophilic algae (cyanophytes sp.) often provided a quick estimation of water temperatures from a distance of several tens of meters. Thermophilic algae were recognized in water that ranged in temperature from 40°C to 70°C, and they have been described and identified in hot springs throughout the western United States (Castenholz, 1969; Castenholz, 1973; Castenholz and Wickstrom, 1975; and Jackson and Castenholz, 1975). Many hot springs support large, thick red-green banded algal mats, which were used as targets for this study.

An aerial survey technique, consisting of low-altitude color photocoverage of suspected thermal springs, was developed and tested at nine sites in Nevada. The technique is based, in part, on the successful recognition of thermophilic algae from several different altitudes in a fixed-wing aircraft. The purpose of this study is to provide a quick, cost-effective reconnaissance of thermal areas which are inaccessible by four-wheel drive vehicles, pack horse, and foot.

THERMOPHILIC ALGAE

Natural growths of thermophilic algae are temperature dependent and their growth patterns accurately reflect isothermal boundaries in a thermal discharge (Castenholz, 1973). In the Basin and Range Province, two species of thermophilic algae dominate the hot springs: Synechococcus lividus, a dark green colored mat-forming algae that may exist in waters ranging in temperature from 55°C to 70°C, and Oscillatoria teribriformis, a red-orange colored mat-forming species that may co-exist with Synechococcus at the low end of its temperature range. Although these two species are very distinctively colored, other less brightly colored species have also been identified in hot springs in Nevada such as Microcoleus sp. and Arthrospira sp. (Joseph L. Mahoney, personal commun., 1978). The presence of these and other organisms may mask or distort the configuration of the red and green banding.

Throughout the Basin and Range Province, thermophilic algae live in extensive colonies (mats) along the banks of non-acid hot springs. The distinctive coloration is easy to recognize on the ground, often from a distance of 30 m or more. Thermophilic algal mats may be found in hot springs at any time of the year; their survival is based directly on water temperature and pH. However, their growth may be limited by several external factors including arthopod and insect herbivors, co-existing thermophilic algae, water chemistry, water depth, flow rate, and the influence of man. For a more complete discussion of the ecology of thermophilic algae, the reader is referred to Castenholz, 1969.

FLIGHT PLANS

In order to overcome some of the access problems that are inherent in any exploration program in the Basin and Range Province, two flight plans, covering both known thermal and non-thermal springs, were flown in the Spring of 1979. The flights included a total of nine sites (see fig. 1) which were photographed in color at three different altitudes. A turbocharged Cessna 206, equipped with a Wild RC-10 camera, set at a shutter speed of 1/1000 second, was used for all flights. The film used was Kodak Aerocolor 2445. The Wild RC-10 camera was selected because of its versatility under varying light conditions; the camera is equipped with an automatic exposure meter. The near infrared spectral reflectance was measured for several artificial and natural red and green targets to determine the presence of any wavelength unique to those targets. That information would have been useful for film selection and processing. Those measurements, however, did not yield any data useful to this study.

FIGURE 1. Location of surveyed sites.

CRITERIA FOR THE RECOGNITION OF THERMOPHILIC ALGAE

The configuration of thermophilic algal colonies is based largely on the configuration of isotherms in a thermal stream (Castenholz, 1973; Castenholz and Wickstrom, 1975; Jackson and Castenholz, 1975). In general, green-colored algal mats (Synechococcus sp.) grow in water with a temperature range of 50°C to 70°C. As temperatures decrease away from the source of the water, red-orange colored algal mats (Oscillatoria sp.) begin to coexist with Synechococcus and are the dominant species in the temperature range 30°C to 50°C. The result is a red-green banded algal mat which may vary in size from .5 m to over 100 m. In addition to the red-green banding, areas of no growth (bare spots) may also be diagnostic. Algal mats are restricted to water temperatures less than 70°C and bare spots are common near high temperature water vents and fumaroles. This feature is particularly obvious at the Hualapai Flat Hot Springs and the McLeod Ranch Hot Springs. Figure 2 is a schematic of the red-green algal banding and associated bare spot.

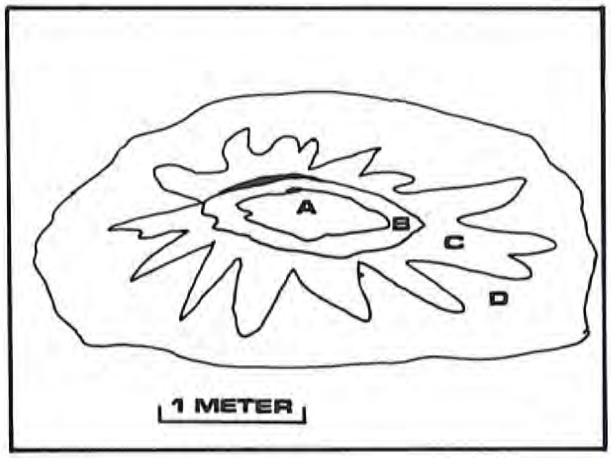

FIGURE 2. Schematic of algae diagnostic features. A. Hot spring vent; B. Bare spot; C. Green algae mat; D. Orange algae mat.

RESULTS

A summary of results is presented in table 1. Algal growths were postively identified in 4 of the 8 hot springs surveyed. No thermophilic algal features were identified in any of the photographs of the Potato Patch cold springs. However, no such features were identified at sites 2, 3, 4, or 5. These springs represent some of the largest and hotest springs in northern Nevada. On the other hand, algal diagnostic features were easily recognized at sites 6, 7, 8, and 9, which are also very hot and as extensive as sites 2 through 5. Although algal growths can be seen from the ground at all 8 hot spring sites, only those at sites 6 through 9 could be recognized from the air. The algal growths at sites 2 through 5 are less brightly

colored than those at sites 6 through 9, and this may have been caused by the coexistence of other thermophilic species.

Another problem that contributed to the limited success rate at sites 2 through 5 was slight image motion at the lower altitudes. This implies that this survey technique is limited to targets greater than 2 m in diameter. At elevations of 1000 ft. above terraine, targets less than 2 m in diameter cannot be distinguished, and at 400 ft. above terraine they are distorted by image motion. For algal mats larger than 2 m in diameter, image motion does not appear to be a problem.

TABLE 1. Summary of results of flights and diagnostic features.

Site number	Site name	Elevation above ground	Red algae	Red-green banding	Bare spot	Measured temperature	Comments
1	Potato Patch Springs	4000 1200 400	no no no	no no no	no no no	17°C	Light green algal growths over the entire length of the discharge.
2	Great Boiling Spring	4000 1200 400	no no no	no no no	no no no	70-100°C	Very deep pools may limit area for extensive growth, area is also partially developed.
3	Trego Hot Spring	4000 1200 400	no no yes?	no no yes?	no no no	83°C	Target is very small, discharge channel is deep.
4	Black Rock Hot Springs	4000 1200 400	no no no	no no no	no no no	65-90°C	Similar to 2 and 3.
5	Double Hot Springs	4000 1200 400	no no no	no no no	no no no	95°C	Similar to 2, 3 and 4.
6	Hualapai Flat Hot Springs	4000 1200 400	yes yes yes	no no no	yes yes yes	40-98°C	Algae growth is on a small fan in shallow water; bare area is a fumarolic vent; algae not recognized in neighboring springs.
7	Darrough Hot Spring	2000 1000 400	yes yes yes	yes yes yes	no yes yes	50-90°C	Extensive red algal growth in tributary streams, may indicate large flow rate.
8	McLeod Ranch Springs	2000 1000 400	no yes yes	no yes yes	no yes yes	25-83°C	Algal growths are restricted to immediate vicinity of hot springs, may indicate small flow rate
9	Spencer Hot Spring	2000 1000 400	yes yes yes	no yes yes	no no no	50-65°C	One of two springs shows extensive banding.

REFERENCES

Castenholz, R. W., 1969, Thermophilic blue-green algae and the thermal environment, Bacteriological Reviews, v. 33, no. 4, p. 476-501.

_____, 1973, Ecology of blue-green algae in hot springs, (in) The Biology of Blue-Green Algae, N. G. Carr and B. A. Whitton, eds., Botanical Monographs, v. 9, Blackwell Scientific Publ., London, p. 379-414.

Castenholz, R. W. and Wickstrom, C. E., 1975, Thermal streams (in) River Ecology, B. A. Whitton, ed. Studies in Ecology, v. 2, Blackwell Scientific Publ., London, p. 264-285.

Jackson, J. E. and Castenholz, R. W., 1975, Fidelity of thermophilic blue-green algae to hot spring habitats, Limonology and Oceanography, v. 20, no. 3, p. 305-322.