



## Organic geochemical characterization of the density fractions of a Permian torbanite

ZHIWEN HAN, MICHAEL A. KRUGE, JOHN C. CRELLING and B. ARTUR STANKIEWICZ

Department of Geology, Southern Illinois University, Carbondale, IL 62901, U.S.A.

**Abstract**—Two distinct organic components, the *Botryococcus*-related alginite (*Reinschia*) and the amorphous organic matrix, were isolated by high-resolution density gradient centrifugation (DGC) from a Permian torbanite (New South Wales, Australia). On the density profile, the alginite (1.03–1.10 g/ml) and the matrix (1.16–1.21 g/ml) appear to be two distinct peaks. With fluorescence microscopy, the alginite shows bright yellow to orange fluorescence and well-preserved algal structure, whereas the matrix has a reddish brown fluorescence of medium intensity. The H/C and O/C atomic ratios indicate that the alginite is equivalent to a Type I kerogen, whereas the matrix falls into the Type II kerogen category. The more “heavy” O and S, and less “light” H content in the matrix also helps in explaining the higher density of the matrix relative to the alginite. Flash pyrolysis-GC/MS of the CH<sub>2</sub>Cl<sub>2</sub>-extracted density fractions shows that the pyrolyzates of both the alginite and the matrix are dominated by normal alk-1-enes and alkanes, which range up to C<sub>31</sub>. However, these normal hydrocarbons are relatively more abundant in the alginite than in the matrix. The alginite also produced a *n*- $\alpha,\omega$ -alkadiene series which was not detected in the matrix. Compared to the alginite, the matrix pyrolyzate is enriched in C<sub>19</sub>–C<sub>31</sub> straight-chain aliphatics and aromatic, phenolic and hopanoid compounds, suggesting that the matrix was formed through incorporation of degraded algal material and humic matter. The higher Methylphenanthrene Index (MPI) value of the matrix pyrolyzates relative to the alginite indicates that the MPI is affected by organic matter type.

**Key words**—density gradient centrifugation (DGC), torbanite, *Botryococcus*-related alginite, organic matrix, flash pyrolysis-gas chromatography/mass spectrometry

### INTRODUCTION

Torbanites are vitrinite-poor coals that macroscopically have a massive appearance and often show conchoidal fractures. The use of torbanites in the shale oil industry brought them into special economic and social prominence in the last century and earlier this century. Their occurrence also stimulated great scientific interest soon after the Scottish torbanite was discovered in 1850. However, it took scientists nearly a century to recognize that torbanites were derived mainly from a single green alga comparable to the extant *Botryococcus braunii* (Thiessen, 1925; Blackburn and Templey, 1936; Belcher, 1955). Thereafter, understanding of the nature of the extant *Botryococcus* algae has been considered the key to the elucidation of the origin of torbanites and the related kerogens in oil source rocks. Therefore, investigations into the properties of the extant *Botryococcus braunii* have been conducted intensively and significant progress has been made (e.g. Maxwell *et al.*, 1968; Wake and Hillen, 1981; Largeau *et al.*, 1980; Dubreuil *et al.*, 1989; Metzger *et al.*, 1992). The resulting insights about the extant algae have been continuously applied to the fossil equivalents (e.g. Cane and Albion, 1971; Largeau *et al.*, 1984, 1986; Derenne *et al.*, 1988). However, torbanite is not petrographically homogeneous. In addition to the notable *Botryococcus*-related alginites, a major

component is the amorphous to fine-grained matrix. Macerals derived from higher plants such as sporinites, detrital vitrinite and inertinite are also commonly present. Therefore, it is not surprising that the previous comparative studies between the extant *Botryococcus* algae and bulk samples of torbanites tended to be less than satisfactory.

The heterogeneity of torbanites was recognized and reported soon after the Scottish torbanite was found. However, because of the difficulty in separating the various components in torbanite, almost all previous chemical studies of torbanites were conducted on bulk samples instead of the individual components. To our knowledge, the first comparison of the algal body and the matrix in torbanite was done by Landais *et al.* (1993), using *in situ* transmission micro-Fourier transform-infrared spectroscopy.

Recently, with the successful application of the density gradient centrifugation technique to the separation of macerals in humic coals (Dyrkacz and Horwitz, 1982; Dyrkacz *et al.*, 1984; Crelling, 1988, 1989), more attention has been focused on the characterization of the isolated density fractions of coals and kerogens (Senftle *et al.*, 1986; Kruge *et al.*, 1989, 1991; Kruge and Landais, 1992; Nip *et al.*, 1988, 1989, 1992; Stankiewicz *et al.*, 1993). In this paper the DGC technique was used to separate the various organic components in a Permian torbanite from