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Environmental and tectonic influences on the formation and distribution of carbonate nodules above the Springfield coal seam, southern Illinois Basin

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Abstract

Carbonate nodules have been encountered for many years in the southern Illinois Basin, in parts of southern Illinois, southern Indiana, and southwestern Kentucky. The nodules occur as oblate spheroids of calcium carbonate that are isolated in the shale immediate roof of coal mines. They are common in the Springfield coal seam, known as the No. 5 seam in Illinois, and as the No. 9 seam in western Kentucky. Several different mechanisms have been proposed for the formation of various semi-spherical objects in coal measure rocks. The distribution and association with rooted horizons suggest that carbonate nodules in black fossiliferous shale observed in the roof of a studied mine in the Springfield seam represent pedogenic carbonate paleosols, which formed in a caliche-favoring environment subsequent to Springfield mire deposition. This interpretation is supported by $^{87}Sr/^{86}Sr$ isotope ratios of 0.710893 ± 13 to 0.711035 ± 12, which indicate a freshwater rather than seawater source.

Petrographic examination of rock textures and mineral grains indicates that nodules collected from two Illinois Basin coal mines are composed of subangular grains of fine-grained, crystalline microspar. Although the carbonate is not ferroan, iron hydroxide stains interstices between microspar grains. The rounded, commonly pinched boundaries of nodules truncate commonly imbricated microspar grains. In contrast, concentric growth patterns are not observed except as defined by secondary, subhedral to euhedral pyrite crystals that form a diffuse, concentric replacement zone around the nodule's outer rind. Polished slickensides, with well-developed radial slickenlines, are developed at highly compacted margins in black shale or mudstone that commonly encases the carbonate nodules.

Of the 450 carbonate nodules documented at a study mine in the southern Illinois Basin, the long axes of 36% are preferentially aligned parallel to regional structures such as anticline axes and drag folds that are interpreted to have formed in response to compression during the Late Pennsylvanian-Permian Alleghanian orogeny. Mapping also suggests that clusters of carbonate nodules are spatially associated with the trends of low-angle drag folds in the immediate roof of the Springfield seam at the study mine. The preferential elongation and distribution with respect to tectonic structures suggest that regional

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compression influenced the shape and distribution of carbonate nodules, and that nodule lithification may have been approximately contemporaneous with regional deformation.
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Keywords: Carbonate nodules; Rhizolith; Pedogenic carbonate; Springfield seam; Illinois Basin

1. Introduction

Spheroidal textures are periodically encountered in coal measure rocks, and have a wide variety of origins. In Pennsylvanian-age coal measure rocks of the Illinois Basin, spheroidal carbonate nodules are a common occurrence above the Springfield coal seam, known as the No. 5 seam in Illinois and the No. 9 seam in western Kentucky. These differences in designation for the same seam are a result of local differences in the sequence of seams, and the fact that seam correlation was not extended across the Ohio River during initial coal exploration.

Carbonate nodules represent a mining danger due to their propensity to drop out of the roof along highly polished slickensides, which encase the nodule until undercut by mining (Fig. 1). Large concentrations of carbonate nodules also tend to degrade the beaming capacity of the immediate roof. Although this situation remains a potential hazard, miners have recognized this source of danger and routinely install supplemental supports to prevent nodules from falling from the roof. In other cases, the carbonate nodule-bearing horizon is removed entirely during the mining process by cutting out the immediate roof. A less common source of injury, and in one case a fatality, associated with carbonate nodules occurs when continuous miner bits break off and become projectiles.

Fig. 1. Typical nature of carbonate nodule exposure in the immediate roof. Note what appear to be concentric compaction rings in black shale around the nodule, and slickenlines that are vertical and longitudinally arrayed on the nodule surface.

A variety of terms have been applied to spheroidal objects encountered in coal mines, causing some confusion when material of differing composition and origin is referred to in a broad sense. The terms “coal ball”, “concretion”, “sulfur ball”, “siderite nodule”, and “head” have all been applied variously to the same or different spheroidal materials in Illinois Basin coal seams. For consistency, the term “carbonate nodule” is herein used to describe the spherical to oblate spheroidal masses of calcium carbonate that are encountered generally in the immediate roof of some coal seams (Fig. 1). Carbonate nodules are different from coal balls, which are commonly interpreted as calcium carbonate-cemented masses of peat (Mamay and Yochelson, 1962) or physically if not chemically preserved organic matter (Lyons et al., 1984). They are different from concretions, which are characterized by an internal structure of concentric growth zones that appear to be absent in carbonate nodules, and they should be differentiated from sulfur balls, which may refer to masses of iron sulfide without any calcium carbonate, although pyrite commonly forms a diffuse to solid rind on carbonate nodules. They appear to be different from siderite nodules, which are commonly also referred to as “kidney beds” in the southern Illinois Basin, although the chemical similarities or differences between kidney beds and carbonate nodules, or the chemistry of carbonate nodules, have not been well documented. They have been informally referred to by miners as “heads”, due to the similarity of some of the nodules’ spherical shape to a human head. It is not clear if the term “nodular limestone” may have been applied to carbonate nodule horizons.