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Carbon with diamond structure in phlogopite in peridotite, Barr Slope Mine, Dixonville, Pennsylvania

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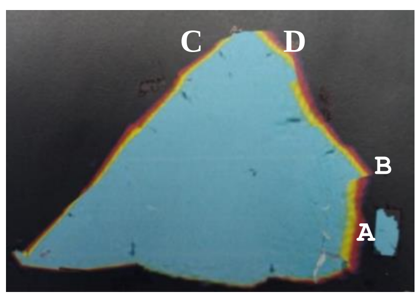
Introduction

Phlogopite laths in underground Lower Freeport bituminous coal seams at Barr Slope (BS) Mine in Rayne Township, Dixonville, Indiana County, Pennsylvania, and associated Tanoma Mine, 2 km west to BS Mine, were studied. Geological setting and descriptive petrography are in Honess and Graeber (1924, 1926). Bikerman et al determined K-Ar age to be 349.6+/- 1.5 Ma . Preliminary K-Ar weighted mean age measured by Dr. Francis O. Dudas (Massachusetts Institute of Technology) utilizing 5 platy large prismatic phlogopite lathe specimens in this study yielded 341+/-4.3 Ma (2δ), with the larger 2δ attributable to uncertainties of alteration and large dimensions (approximately 2-3 cm × 3000 μm . Phlogopite coexists with forsteritic olivines, chrome diopsides, garnets, apatites, Fe-Ti oxides, various carbonates, serpentine and matrix phases (Chan, 1992). Modal percentages of phlogopite range from approximately 20 to 35, with rarer portions greater than 40. Not only abundant in presence, they are single crystals (megacrysts, phenocrysts), some are in exceptional quality for study.

Table 1. Composition of phlogopite

SiO_2	39.1
TiO_2	1.34
Al_2O_3	11.8
Cr_2O_3	0.14
FeO	9.82
MnO	0.33
MgO	22.34
CaO	0.16
K_2O	10.41



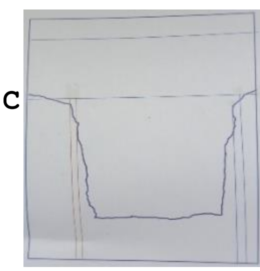
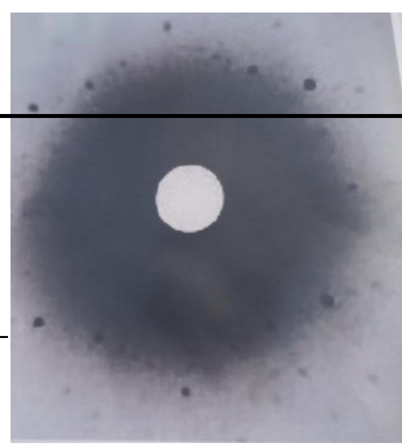
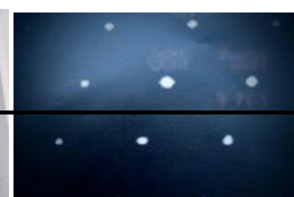


Table 2. Cell parameters of carbon

Crystal system	cubic
$\boldsymbol{a} = 1/\boldsymbol{a}^* =$	3.58+/- 0.02
V =	0.0459 nm
Z =	2
Radiation Mo K α	λ = 0.71073 A





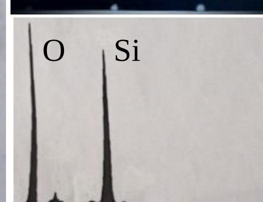


Figure 1. Etch pit in phlogopite
Figure 2. Depth of walls C to AB
Figure 3. Laue of 4 fold rotational axis
Figure 4 Coesite near hexagonal symmetry
Figure 5 EDAX of coesite

Table 3. Single crystals refinement and cell parameters of phlogopite

a	5.35
b	9.23
c	10.17
β	***100.02***

Table 4. Preliminary carbon isotopic composition measurements by P. Deines yielded 4.4x to 10.1x

Sample	<Delta>13C o/oo with respect to the PDB standard		
Dx 1.4	8.3 x	Dx2.4	7.2 x
Dx2.1	10.1	Dx2.6	7.9
Dx2.3	4.4	Dx2.a	6.8

Methodology

Structurally anisotropic presence of etch pits of carbon on basal (001) face of phlogopites is near exclusive. Laborious intensive searches on over 50 {hk0} found no carbon trigons or inverse trigons. Or that their presence has been erased by reactions due to reactivities at {hk0} and elsewhere higher than (001); whereas basal (001) faces remained relatively inert.

Spatial characterization of etch pits

Step height of etch pits were measured. Schematic optical setup of Fizeau laser (633 nm) 3D interferometry (University of Minnesota Corrosion Center) is described in Zygo Corp. web. Resolution is λ/100, repeatability λ/2000. A Broker Nanoscope V (University of Minnesota Materials Science) AFM positional resolution is 0.1 nm laterally, 0.01 nm vertically, imaging resolution 1 to 10 nm. Step height of typical mica layer should be around 10 A. Observed Step heights conform to that of carbon, or multiples of, consistent with construction/deconstruction of the diamond lattice structure per layer carbon at a time. Large number of such steps identified across vertical (Z-axis) side walls of pits is consistent with great number of episodic fluctuation of CO_2 /H_2O ratio over history. Sharply steep walls, or segments of, is consistent with competitively rapid ascent.

Polygonization of trigons by truncation of trigons and inverse trigons often did not result in a theoretical or perfect hexagon, but rather 4 sided or 5 sided (Figure 1B) due to handedness (right handed vs. left handed) of spiral. Edge AB advanced faster than edge CD, whereas Point E still remain not yet truncated by clockwise motion of Burgers vecter. Workable trigons and inverse trigons, low index faces, large terraced faces were utilized for structural and isotopic (by P. Deines, Penn State) analyses. Low index faces are prominent and utilitarianly useful, some exceeding 10 mm×10 mm. Carbon is isometric.

Composition

Electron microprobe analysis carried out at University of Chicago, U. S. Bureau of Mines, both utilized automated Cameca sx-50, 15kV, 30 nA, corrected for matrix with ZAF. Results differ insignificantly. Spectra of P, S, Cl with counts usable appear in both instruments also. Specimens were coated simultaneously with standards in Cressington carbon evaporators to obtain identical thickness of carbon.

Carbon

Laue diffraction pattern located 4-fold rotation axis (looking down). Fainter spots can be clarified with increased exposure time, adjusted film to specimen distance. Miller indices can be identified, orientation matrix, *hkl* solved. Stereographic projection can be utilized to rotate to identify other symmetry planes.

Coesite

Coesite lamellae were located in clinopyroxene. Presence of coesite is a supporting evidence.

Summary

Considering the coal seam's thickness system wide over 3 mines (Bar Slope, Tanoma, Clymer No. 1 and No. 3) is 42 inches, possible mechanisms are contemplated. Oxidative etching is consistent with initial pitting on phlogopite (100). Basal etched phlogopite is pathway. Carbon filled in. Repeating adsorption/description of vapors evolved with stability of phlogopite (e.g. P. Wyllie (1977, 2nd ikc; 1979; and pers. Comm)) and limitations pertinent to stability. After emplacement, coal seam modified phases. **Other American Peridotites and Predictions**

Phlogopite with etch pits has been found in a number of other American peridotites, including Fayette County. Neal and Taylor (1989, Scott County, Arkansas, page 209; and Taylor, written Comm.) "… holes in the interior of phenocrysts …". Patel and Ramanathan (1962) attempted prediction of etch pit locations by utilizing mirror symmetry operation. This process is labor intensive and rudimentary when applied to Dixonville specimens which are larger in dimension. Rudimentary success is found utilizing this symmetry operation, while other symmetry operations (2 fold rotational, twin laws) unsuccessful. Of the small number of etch pits as predicted, the dimensions are not identical. Possible point defects, extended defects, or polytypism (Tolansky 1945, 1946) await further study. Specimen preparation could also contribute in that it is not practical preparing a specimen less than 2500-3000 *u*m in thickness for a lathe 2 cm and above lengthwise. Symmetry of a single crystallographical basal plane sheet is not identical as symmetry of a bulk specimen due to Burgers vector spiral. Predictions chemically was attempted by estimating etch rate laws. Curverture of wavy basal planes due to spiraling and inclusion of diamond, which is fluorescent, are attributable to the dramatic colors of phlogopite (Mbalu-Keswa, 2004, "splashes of vivid hue…")

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