Diversity of the Kokchetav metamorphic diamonds and their formations related with H$_2$O-rich fluid conditions

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**Diamonds at Kumdy-kol, Kokchetav**

Short summary of our previous studies

**Dolomite marble**
- **Representative diamond-bearing rock in the Kokchetav**
- **Very high abundance** (max. 2700 carat/ton)
- **Two-stage growth**:
  - 1st stage $\delta^{13}C = -15$ to $-8\%$, **2nd stage**: $\delta^{13}C = -27$ to $-17\%$
  - 2nd stage diamond formed from C-bearing $\text{H}_2\text{O}$ fluid
    - High nucleation rate
    - Quick crystallization

**Grt-Bt gneiss**
- High abundance
- **No 2nd stage growth**
- Growth and dissolution (?)

**Grt-Cpx rock (Dia-bearing)**
- Low abundance
- Large-grain > 100 $\mu$m
  - Overgrowth on fine grain
  - Low nucleation rate
  - Slow crystallization from $\text{H}_2\text{O}$ fluid

**Calcite marble**
- Very low abundance
  - (61 grains only in Di)
- **No 2nd stage growth**
- Growth and dissolution (?)
- Small FWHM of Raman

**Tur-Qtz-Fel rock**
- Dia in maruyamaite
- **No 2nd stage growth**
- Small FWHM of Raman
Two stage growth in dolomite marble

S-type: ca. 80% in dolomite marble

1st stage: core of S-type, R-type
2nd stage: rim of S-type, T-type

Scale bar: 10 micrometers
Two-stage growth of diamond

Carbon isotope of S-type microdiamond

Core: $\delta^{13}\text{C} = -14$ to $-9 \%$ heavier
Rim: $\delta^{13}\text{C} = -26$ to $-15 \%$ lighter

R-type: $\delta^{13}\text{C} = -15$ to $-8 \%$
$sp^2$ carbon in 2nd stage diamond

Relics of metastable intermediate C phase for diamond from C-bearing $H_2O$-fluid

After Miura & Ogasawara (2014) (AGU2014F V13B-4771)
Microdiamonds in gneisses

- Abundant
  - But one order lower than in dolomite marble
- Variable morphologies
  - Granular, cubic, cubo-octahedral, spinel twin, etc.
- No 2\textsuperscript{nd} stage growth
  - Dissolution of diamond into H\textsubscript{2}O fluid is possible.
- Host rock gneisses are possible H\textsubscript{2}O source and the light C isotope source
Diamonds in Grt-Bt gneiss
Diamond in Grt-Cpx rock

- Minor amount
- Extremely large-grained: > 100 μm
- Find-grained Dia (new discovery: AGU2014F V13B-4779)
- Cubic overgrowth on fine-grained
- **Low nucleation rate and slow growth**
  - Fine-grained Dia: a seed crystal
Grt-Cpx rocks (Dia-bearing and Dia-free)

Products of strong metasomatism of carbonate + silicate mixtures at UHP

Diamond-bearing

Grt + Cpx
Like “skarn”
Not eclogite

Diamond-free

No Diamond
BUT UHP

First description:
Sobolev & Shatsky (1990)

Description:
Sakamaki & Ogasawara. (2014: IGR V.55)

UHP evidence:
Coesite exsolution from supersilicic titanite
Large-grained cubic diamond overgrowth on fine-grained one

**FWHM**
1: 4.71, 2: 4.36

- **Fine-grained (new)**
- **Cubic**
- **Intensity**
- **FWHM**

**Peak position**

- Z = -10 μm
- 20 μm
- 50 μm

(a.u.)

(cm⁻¹)

- 1331.9
- 1331.8
- 1331.7
- 1331.6
- 1331.5

- 8000
- 7000
- 6000
- 5000
- 4000
- 3000
- 2000
- 1000

- 4.7
- 4.6
- 4.5
- 4.4
- 4.3
- 4.2

2 μm
Titanite–bearing Calcite marble

- Coesite exsolution in titanite
- Supersilicic titanite
- Min. P > 6 GPa
- Diopside with K-Fel Phe lamellae
- XCO₂ of titanite stability
  - extremely low (< 0.02)

Diamond: 61 grains
- in diopside
- no 2nd stage growth

No diamond part

Dia-bearing part
Microdiamonds in Tourmaline Qtz-Fel rock

- Contains diamonds
- No 2nd stage growth
- Maruyamaite: stable at UHP and under H$_2$O fluid

New mineral 丸山電気石(K-tourmaline)
New mineral “maruyamaite”
(K-dominant tourmaline domain includes diamond)

丸山電気石
IMA No. 2013-123

Berryman et al. (2014):
K-tourmaline is stable at UHP
and K-rich H₂O fluid
Evidence of $\text{H}_2\text{O}$ fluid

Micro-FTIR spectra

(OH) and $\text{H}_2\text{O}$ in host garnet

(OH) and $\text{H}_2\text{O}$ in host Cpx

$\text{H}_2\text{O}$ in diamond (Grt-Cpx rock)
OH/H$_2$O in Grt in dolomite marble

Micro-FTIR spectrum of garnet (Yazaki, 2007: unpublished data)

FT-IR spectra
ZW45-y2-o: Spot no. 5

(OH)$^-$ in Grt structure

H$_2$O as submicron size fluid inclusions

Evidence of H$_2$O fluid
Grt-Bt-gneiss

sample no. ZW54a

OH: 197 ppm
H$_2$O: 110 ppm

structural OH in Grt
3568

structural OH in Phe
3655

molecular H$_2$O
3403

Total water (OH + H$_2$O) : 63-332 ppm
**OH/H$_2$O in Grt in Grt-Cpx rocks**

Micro FT-IR spectra

**Dia-free Grt-Cpx Rock**

Structural OH in Grt

- OH: 761 [ppm wt. H$_2$O]
- H$_2$O: 380 [ppm wt. H$_2$O]

**Dia-bearing Grt-Cpx Rock**

Structural OH in Grt

- OH: 997 [ppm wt. H$_2$O]
- H$_2$O: 1216 [ppm wt. H$_2$O]
Direct evidence for diamond formation in H$_2$O fluid

H$_2$O in diamond in Grt-Cpx rock

Micro FT-IR spectrum

The details will be presented at AGU2015F (V11C) by Sakamaki, Ogasawara & Schertl
Intraslab UHP metasomatism

(After Imamura et al., 2013; Ogasawara 2004; 2009; 2014)

H₂O from silicate rocks carried C, K, Ti, etc. into carbonate/calcsilicate rocks.
Conclusions

- Kokchetav metamorphic diamonds show diverse features
  - in abundance, distributions in host minerals and host rocks
  - in morphology, Raman, CL and PL spectra, C isotope, etc..
- Formations of these diamonds are complicated, but some may be explained by H$_2$O-fluid infiltration in subducted continental materials.
- The presence of H$_2$O fluid was confirmed in host minerals as OH and H$_2$O, and in diamond in Grt-Cpx rock.
- Some of the diamonds crystallized from C-bearing H$_2$O fluid:
  - 2$^{nd}$ stage growth (T-type and core of S-type) in dolomite marble
  - Cubic over growth (?) in Grt-Cpx rock
- Dissolution of diamond into H$_2$O fluid could be possible in some rocks without 2$^{nd}$ stage growth.
  - Grt-Bt gneiss, UHP calcite marble

Thank you for your attentions!