PETROLOGY OF TARGET DOLERITE IN THE CHICXULUB PEAK RING AND A POSSIBLE SOURCE OF K/Pg BOUNDARY PICOTITE SPINEL.

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Introduction: When K/Pg boundary ejecta in Haiti was discovered, leading to a continental impact site on the Yucatán Peninsula (Mexico), a small component of picotite spinel was found with ejected shocked quartz and feldspar. It was suggested [1] that the continental target rocks of Chicxulub might contain a small amount of mafic rocks, an idea that, until now, has remained untested.

Recent drilling of the ~180 km-diameter Chicxulub crater during International Ocean Discovery Program (IODP) and International Continental Scientific Drilling Program (ICDP) Expedition 364 recovered shocked and uplifted target lithologies from the peak ring of the impact structure [2], further advancing an understanding of peak ring formation in large impact craters [3]. Borehole M0077A recovered core samples of, from top to bottom, post-impact sediments, reworked and primary impactites, and the predominantly granitic basement cross-cut by suevite and impact melt rock, cataclastic dikes, and igneous intrusions, before bottoming at 1335 mbsf [2].

Impactites and basement rocks have been, to variable degrees, hydrothermally altered [4]. The crystalline and metamorphic target rocks of the Chicxulub crater mainly consist of granitoids, gneisses, amphibolites, mica schists, and meta-quartzites [5]. We here present petrologic results for newly discovered dolerite that intruded the granitoids of the Chicxulub crater's peak ring in pre-impact time and were later impact-deformed, with a focus on semi-opaque and opaque spinel group minerals (SGM). The SGM are compared with ejected SGM earlier reported in K/Pg boundary sediments in Haiti [1,6,7] and the Raton Basin of Colorado and New Mexico, USA [8], to test for a potential common provenance. These target-derived SGM are distinct from the vapor-condensed, Ni-rich magnesioferrite crystals also found at the K/Pg boundary.

Samples and Analytical Methods: Four dolerite splits, (1) thick-section sample 144-1-36-38 (core 144, section 1, 36-38 cm) from a depth of 866 mbsf; (2) thin-section sample 151-1-30.5-32.5 from a depth of 887 mbsf; (3) thin-section sample 222-1-13-16 from a depth of 1084.7 mbsf; and (4) thin-section sample 222-1-70-72, from a depth of 1085.3 mbsf were analyzed using an optical microscope at the LPI, and a JEOL 5910 scanning electron microscope and a CAMECA SX 100 electron microprobe at the NASA–JSC. Samples (1)–(3) are from the central dolerite bodies; sample (4) is from a lithic breccia zone at the lithologic contact between dolerite and the target granitoids.

Petrography and Geochemistry: All dolerite samples investigated have a typical ophitic texture (Fig. 1a), and consist of ~35–45 vol% variably altered plagioclase, ~30–40% clinopyroxene, ~20–25% Mg-Fe-(Al-) sheet silicates, ≤5% SGM, and accessory minerals such as Fe-sulfides and calcite. Plagioclase laths up to ~4.5 mm in length show primary domains with magmatic twinning, locally undulous extinction, rare planar features, and have been partially replaced by pseudo-amorphous masses and/or sericitized. Clinopyroxene shows well-developed fracturing. Former olivine phenocrysts, up to ~2 mm in size, have been entirely pseudomorphosed by Mg-Fe-(Al-) sheet silicates that commonly host SGM and µm-sized particles of Fe–Ni sulfide. The crystalline dolerite groundmass is composed of plagioclase, clinopyroxene, mafic sheet silicates, and SGM. Samples (1)–(3) have groundmass crystal sizes ≤600 µm, whereas dolerite sample (4) is significantly finer-grained, with crystals ≤70 µm; this part of the rock seems to have been quenched during intrusion at the host granite contact. Although the surrounding host granite contains shocked quartz with multiple sets of planar deformation features (PDFs) [2], the dolerite, in which no quartz was found, is less obviously shock-metamorphosed, particularly with the overprint of post-impact alteration.

Plagioclase, where preserved, is bytownite, $An_{75–78}Ab_{24–21}Or_{0–1}$, in sample (2) (*n*=8), and $An_{72–80}Ab_{27–20}Or_{0–1}$ in sample (3) (*n*=4). Altered, pseudo-amorphous plagioclase domains in all samples correspond to $An_{34–75}Ab_{64–24}Or_{0–12}$ (*n*=46), but are enriched in Mg and Fe, and often produced low electron microprobe totals. Clinopyroxene is diopside, $Wo_{46–48}En_{31–37}Fs_{22–16}$, in sample (1) (*n*=8); and diopside–hedenbergite–augite, $Wo_{42–45}En_{14–42}Fs_{43–14}$, in sample (2) (*n*=17), and $Wo_{43–46}En_{19–42}Fs_{37–13}$ in sample (3) (*n*=7).

Spinel Group Minerals: Spinel group minerals occur in three main modes in the dolerite: first, irregular-shaped, and locally poikilitic, grains of partially resorbed picotite (and, more rarely, Cr-rich hercynite) with irregular fractures and silicate inclusions (Fig. 1b,c), commonly with epitaxial overgrowths of titanomagnetite (Fig. 1c,d). Picotite/hercynite is preferentially found in sheet silicate domains replacing olivine, but also occurs in the dolerite groundmass. Most of the picotite/hercynite grains are <100 µm in crystal size, however, some aggregates are up to ~500 µm long (Fig. 1c). Second, idiomorphic and locally skeletal crystals of Ti-magnetite with irregular fractures (Fig. 1d) are widespread in the groundmass of dolerite samples (1)–(3); and third, composite, idiomorphic and skeletal grains with cores of Ti-magnetite, commonly surrounded by a microgranular Ti–Fe–Ca–Si-rich exsolution and/or alteration zone (possibly some sort of 'leucoxene'; Fig. 1e), occur in sample (1). The latter two types of Ti-magnetite grains, ≤150 µm in diameter and often associated with small mica flakes likely of the annite–phlogopite series, are abundant in the dolerite groundmass of samples (1)–(3), but were not found in fine-grained sample (4). Neither picotite/hercynite nor Ti-magnetite in the peak ring dolerite show unequivocal signs of shock (e.g., PDFs), but exhibit subplanar to irregular fracturing.

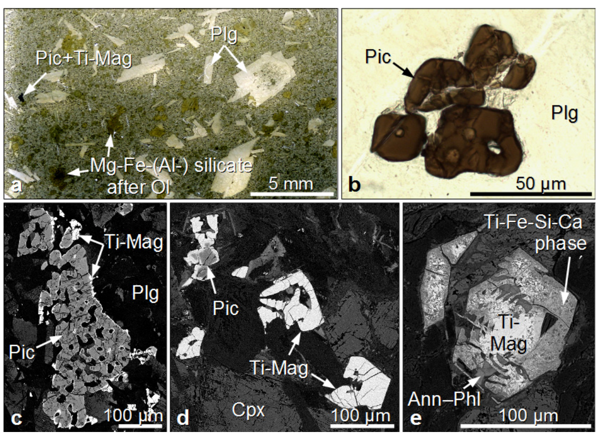

Fig. 1: Spinel group minerals in dolerite from the M0077A core. **a)** sample 222-1-13-16, with larger plagioclase (Plg) laths and former olivine (Ol) replaced by sheet silicates; thin section scan; **b)** translucent aggregate of picotite (Pic) in 222-1-70-72; plane-polarized light; **c)** larger aggregate of resorbed picotite, with titano-magnetite (Ti-Mag) rim in 222-1-13-16; **d)** skeletal Ti-magnetite in 144-1-36-38; **e)** composite grain with a Ti-magnetite core and an outer alteration zone, accompanied by mica of the annite–phlogopite (Ann–Phl) series; c)–e) backscattered electron images (15 kV).

Picotite/hercynite cores in all dolerite samples range within $Hc_{49–69}Chr_{23–39}Mag_{7–13}$ when plotted in the ternary Al-, Cr-, and Fe^{3+} end-member projection of the spinel prism [9] (Fig. 2a), and have $Fe^{2+}/(Mg+Fe^{2+})$=0.32–0.45; $Fe^{3+}/(Cr+Al+Fe^{3+})$=0.07–0.13; Cr/(Cr+Al)=0.25–0.45; and ≤1.2 wt% TiO_2 (*n*=42). Titanomagnetite cores are predominantly $Hc_{8–21}Chr_{0–1}Mag_{78–92}$, with $Fe^{2+}/(Mg+Fe^{2+})$=0.97–1.00; $Fe^{3+}/(Cr+Al+Fe^{3+})$=0.78–0.92; Cr/(Cr+Al)≤0.12; and ~15–21 wt% TiO_2 (*n*=19). Some SGM rims yielded transitional compositions. A summary of compositions of the SGM in the peak ring dolerite, including crystal cores and rims, is presented in Fig 2a–c. One picotite grain and several magnetite grains previously reported from K/Pg deposits in the Beloc Formation of Haiti [1] (with unpub. electron microprobe data from D. A. Kring) are plotted for comparison; no compositional data are available for the shocked SGM of [6,7] and [8] from Haiti and the Raton Basin, respectively.

Possible Relation to Relict K/Pg Boundary Spinel: Both the picotite and several magnetite grains from ejected K/Pg boundary sediments of the Beloc Formation in Haiti [1] have compositions relatively close to those of the SGM observed in the peak ring dolerite. The Haitian picotite is slightly richer in Cr^{3+}, and poorer in Al^{3+} and Fe^{3+}, compared with the picotite/hercynite in the dolerite, and magnetite from the K/Pg boundary plots somewhat closer to the Fe^{3+} end member, but the compositional similarity is important. Other dolerites in the crystalline–metamorphic Yucatán basement are a reasonable source of ejected picotite and magnetite grains found in K/Pg boundary deposits of Haiti [1] and elsewhere.

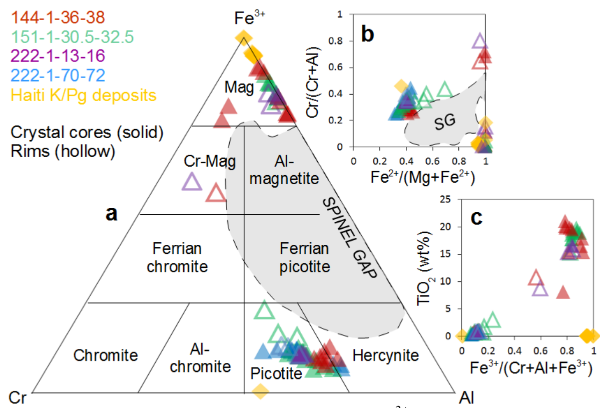

Fig. 2: Ternary diagram for Al-, Cr-, and Fe^{3+} end members (**a**) and additional diagrams (**b, c**) illustrating the compositions of spinel group minerals [9] (cores and rims) in four dolerite samples from Chicxulub core M0077A (triangles), and a number of grains separated from K/Pg boundary sediments of Haiti [1] (diamonds).

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