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MELTING AND MIXING OF TARGET ROCKS, METEORITIC CONTRIBUTION, AND HYDROTHERMAL ALTERATION WITHIN THE ROCHECHOUART IMPACT LITHOLOGIES.

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Résumé : Cette étude porte sur la caractérisation pétrographique et géochimique de 51 échantillons issus de la campagne de forage de 2017 au sein de la structure d'impact de Rochechouart. Toutes les lithologies ont été échantillonnées, avec une attention particulière pour les roches contenant des parties fondues à l'impact car elles contiennent une proportion plus importante de matériel météoritique. En combinant observations pétrographiques et analyses des éléments majeurs et traces, les objectifs sont (i) de vérifier la représentativité des échantillons et d'établir pour la première fois une caractérisation précise de ces impactites forées en 2017 ; (ii) de mettre en évidence les différents processus qui ont lieu pendant et après l'impact : la fusion et le mélange des roches cibles, l'apport de matériel météoritique dans les impactites, et l'altération hydrothermale qui a affecté la structure d'impact.

Introduction: The Rochechouart impact structure (North-West of the French Massif Central) is a deeply eroded crater with no remaining impact-related topography[1] that was formed ~207 Myr ago[2]. Intensive erosion has led the crater floor to outcrop in many localities, which is an uncommon feature among impact structures. Despite this erosion, a suite of proximal impactites is still preserved, including impactoclastites (melt-bearing ash-like deposits), suevites (polymict melt-bearing impact breccias), breccias, impact melt rocks, and shocked crystalline basement (gneiss and granite). All of these lithologies were sampled during the 2017 drilling campaign, which resulted in 18 drill holes (with a cumulative length of ~540 m) located at 8 sites along two 10-km radial transects across the center of the structure[3] (Fig. 1).

Here, we examine the major and trace element compositions of 51 samples from various lithological units and combine these results with petrographic observations. The main objectives are to examine the representativeness of these drill core samples and to trace the effects of melting and mixing of target rocks, the addition of a meteoritic contribution, and the nature and extent of hydrothermal alteration across the Rochechouart structure.

Sample Selection and Methods: Fifty-one samples from 6 drilling sites (Fig. 1) have been selected for this study based on logs established during the 2017 drilling campaign and macroscopic observations of the cores on site. Samples were selected to be as representative as possible of their units by avoiding large clasts, fractures, and heavily altered sections. All major lithologies have been sampled and particular attention was paid to the melt-rich lithologies as these likely contain the highest projectile contribution[4]. All samples have been analyzed for their whole-rock major and trace element compositions, which were obtained using ICP-OES and ICP-MS after alkaline fusion of homogenized sample powders (SARM-Nancy). A subset of 32 representative samples has been characterized by petrographic and mineralogical examination coupled with micro XRF elemental distribution mapping (Bruker M4 Tornado).

Results: Both target lithologies (gneiss and granite) exhibit a phaneritic texture, with comparable modal mineral abundances: quartz (40-70 vol%), feldspar crystals (20-40 vol%), opaque minerals (10 vol%), while the gneiss also contains mica crystals (20-30 vol%). These crystalline rocks display some shocked features, such as fractures, local deformations, decorated quartz grains, fractured garnet crystals, and augen feldspar minerals (in orthogneiss). Depending on the drill cores, either impact melt rocks or impact breccias and suevites overlie the shocked crystalline basement (Fig. 1). Three different impact melt rock types have been identified within the drill cores. At a macroscopic scale they differ mainly by their color: red/brown, yellow, and grey. The red/brown impact melt rock is by far (> 95%) the most abundant within the Rochechouart impact structure and

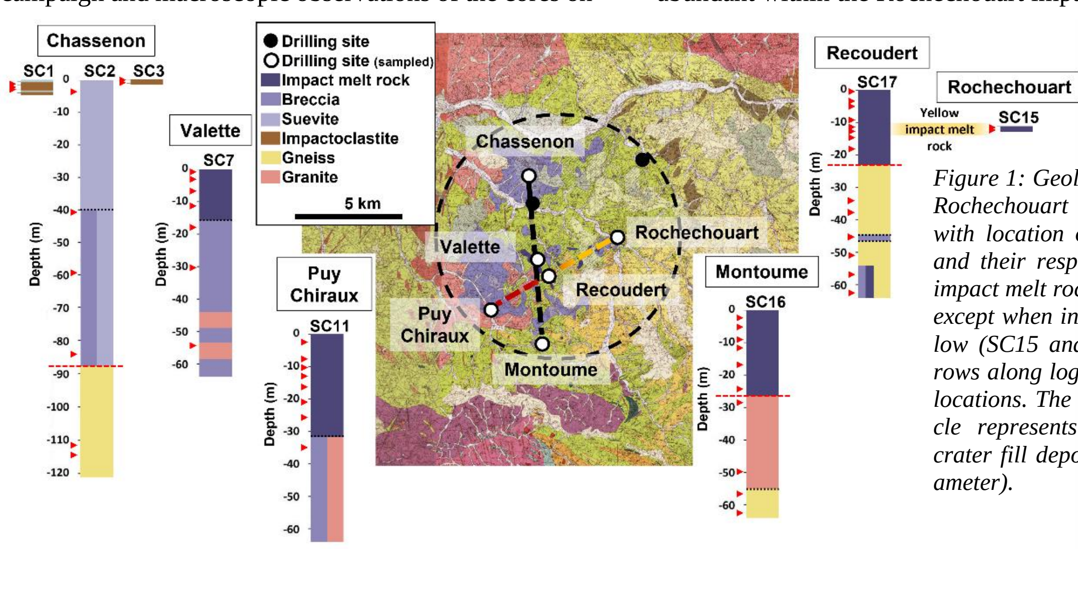

Figure 1: Geological map of the Rochechouart impact structure with location of the drill cores and their respective logs. Most impact melt rocks are red/brown except when indicated to be yellow (SC15 and SC17). Red arrows along logs indicate sample locations. The black dashed circle represents the envelop of crater fill deposits (~ 11 km diameter).

appears mostly in the southern half of the structure (Fig. 1). The yellow impact melt rock is present as a meter-thick layer in the eastern half of the structure (Fig. 1). The grey impact melt rock occurs rarely, as intrusive dm-thick veins. Beside their color, these melts are mineralogically similar and composed of lithic clasts (gneiss and granite; 10-40 vol%) and mineral clasts (quartz, feldspar, mica; 10-50 vol%) embedded in a crystalline groundmass (40-80 vol%). Microlites remain visible in most red/brown and yellow impact melt rocks. Partially digested clasts are more often found in the red/brown impact melt rock than in the yellow one. The grey impact melt rock is characterized by higher abundances of quartz (> 80% vs. ~50%). Impact breccias, both monomict or polymict, are found in several drill cores (SC2, SC7, SC11, and SC17). They are composed of a clastic groundmass (30-50 vol%) with lithic and mineral clasts deriving from the target rocks (50-70 vol%). Suevite is only found in core SC2. This lithological unit is distinct from the impact breccias by the presence of up to 10 vol% melt fragments. Impact melt rocks, suevites, and breccias exhibit clasts with shocked features (decorated quartz, ballen quartz, kinked biotite) and contain secondary carbonates. The impactoclastite unit occurs as centimeter- to meter-thick fine-grained (mostly < mm) stratified intercalations in the upper part of the suevite unit in Chassenon (cores SC1-3; Fig. 1). Angular lithic and mineral clasts (20-60 vol%) and (sub)rounded melt fragments (up to 10 vol%) are embedded in a fine-grained reddish clastic groundmass (40-80 vol%).

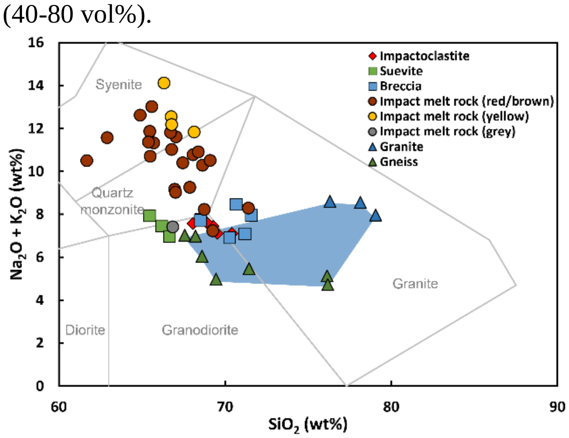

Figure 2 : Total alkali-silica diagram with grey field compositions from[5]. The blue envelop represents the basement composition in Rochechouart area.

On a binary plot of a total alkali versus silica, the basement lithologies display a granodioritic to granitic composition with the highest SiO_2 (~67.5-79.1 wt%) and lowest $Na_2O + K_2O$ (~4.7-8.6 wt%) contents among the sample suite (Fig. 2). The impact breccias overlap or plot close to the range defined by the target rock compositions. The impact breccias, suevites and impactoclastites fall in between the ranges defined by the basement materials and the red/brown impact melt rocks (Fig. 2). A similar pattern can be observed for all other major elements (Fe_2O_3, Al_2O_3, MgO, TiO_2, MnO, CaO). The yellow impact melt rocks exhibit compositions comparable to those of the red/brown ones except for Fe_2O_3 (< 2 wt% vs. ~4-8 wt%) and Al_2O_3 (~18 wt% vs. ~14-17 wt%). Based on CI chondrite normalized trace element spider diagrams, most impactites plot in range of the target rock compositions.

Discussion and conclusions: As shown by petrographic observations and geochemical analysis, the impact melt-rich lithologies are formed by melting and mixing of both granite and gneiss. The two main types of impact melt rock exhibit a heterogeneous spatial distribution, with the red/brown melt rock concentrated towards the southwestern part of the structure, where mostly granites outcrop. In contrast, the yellow impact melt rock is located in the eastern part of the structure, where mainly gneisses are exposed. Both impact melt rock types are found in the center of the structure (SC17), where these are partly mingling. This distribution likely indicates incomplete homogenization of impact melt within the Rochechouart impact structure.

Post-impact hydrothermal alteration strongly affected the samples. All impactites, and especially the impact melt rocks, are enriched in K_2O relative to the target due to K-metasomatism (also seen in Fig. 2). Alteration to clay minerals and secondary mineralization of carbonate and iron oxide minerals are also observed in the thin sections.

All impact melt-rich lithologies are enriched in the moderately siderophile elements, including Ni and Ge (Fig. 3). As these elements are more abundant in most projectile types than in the upper continental crust[8], this highlights the contribution of a meteoritic component to the Rochechouart impact melt.

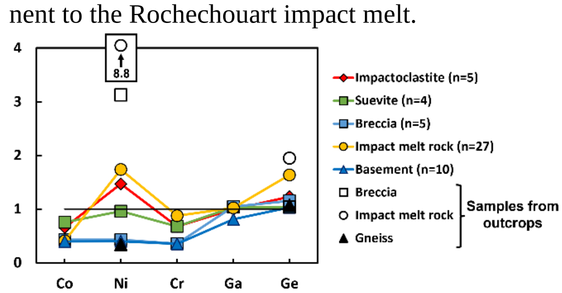

Figure 3: Siderophile trace elements normalized to upper continental crust values[6]. Samples from outcrop data from[7].

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