BIOLOGICAL IMPACT ON WEATHERING OF GRANITOIDS IN THE HIGH TATRA MTS.

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Abstract: Influence of lichen encrustation on weathering of granitoids from the High Tatra Mts. was studied. Presence of lichen promotes biomechanical and biochemical processes of weathering.

Biomechanical processes are caused by penetration of hyphae into minerals. Their intensity is related to the composition of minerals. Biomechanical processes result in fragmentation of the rock. Fragmentation can be stimulated by swelling of hyphae inside minerals in relation to ambient humidity and freeze-thaw processes.

Biochemical processes are influenced by the activity of "lichen acids", dissolved respiratory CO_2, and retention of moisture in the superficial layer of the rock. Increasing degree of fragmentation of the rock and decreasing average fragments size enhance biochemical processes rate because of increase of reaction surface. Biochemical processes cause migration of elements. Lowering of K content in biotite accompanied by increase of Al and Ca content is observed. Fe and Ti are often concentrated near altered biotite. Accumulation of element in lichen thalli is variable and partly related to the chemical composition of minerals (e.g. Ba in vicinity of K-feldspar).

It is difficult to evaluate the protective role of lichen in granite weathering processes. Detached rock fragments are bound beneath lichen thallus but the fragmentation is enhanced by the development of lichens.

INTRODUCTION

Increase of weathering rate of silicate rock under lichen encrustation is commonly suggested however, protective role of lichens is postulated also. Brady et al. (1999) and McCaroll and Viles (1995) determined that intensity of weathering under lichens is 2-18 times or 25 – 50 times higher than in the abiotic case. The crustose lichens can enhance weathering by biomechanical action (biogeophysical weathering) and by biochemical processes (biogeochemical weathering) (Adamo & Violante, 2000, Chen et al., 2000).

According to Lee and Parsons (1999), *Rhizocarpon geographicum* on granite binds mineral fragments and prevent rocks from entering soils. Lichen acts also as thermal insulation inhibiting mechanical disaggregation by freeze-thaw. Silica-rich layer formed during biochemical interaction between lichen and granite plays also a protective role covering mineral surfaces and closing of intragranular pores (Lee and Parsons 1999).

MATERIALS

Granite boulders covered by lichens (*Rhizocarpon geographicum, Umbilicaria cylindrica, Lecanora intricata, L. Polytropa, Protoparmelia badia*) from moraine at the Hala Gąsienicowa were collected. Granite samples from the Kościelec ridge were coated by encrustation of *Rhizocarpon gepographicum* and *Orphiniospora moriopsis*. Rocks studied represent so-called marginal zone type granite and are characterized by different textural types (medium-, coarse- very coarse-grained rocks). Mineral composition is relatively simple. Quartz and plagioclase (of oligoclase composition) are accompanied by K-feldspar, biotite and scarce muscovite. The amount of K-feldspar and muscovite increases in very coarse-grained rocks of pegmatite appearance.

METHODS

Observations of superficial layer of the rocks were performed using JEOL JSM 5410 and HITACHI S4700 scanning electron microscopes. Contact zones lichen crust-rock and several millimetres thick outermost layer of the rock were studied. Both rough surfaces and polished preparations were observed after carbon coating. Chemical composition of components of studied samples was determined using energy dispersive spectrometres (EDS) VOYAGER 3100 and VANTAGE (manufactured by NORAN). Optical microscopy (transmitting and reflected light) was used also.

RESULTS

A bleached layer (from 0.5 to 1.0 mm thick) or diffused rusty brown zone (up to several mm thick) can be observed beneath lichen layer. The occurrence of bleached or rusty layer can be related to the mineral composition of granite (e.g. abundance of biotite and other iron-containing minerals) or to the assemblage of lichens. More detailed observations are needed for establishment of these relationships.

The lichen layer is tightly attached to the rock substrate. Numerous mineral fragments (up to few μm in size) are dispersed in the lichen thallus (Fig. 1, 2). The number of mineral fragments increase towards the rock surface. In local engulfment polygrained aggregate dozen of μm thick are present between rock surface and lichen crust. In the outer part of lichen encrustation variable concentrations of Al, Si, K, Ca, Fe, S, and P were noted (beside C) using SEM-EDS method. Irregular rounded forms very rich in Al were found inside thalli.

The relatively coarse grained texture of granite allows determination of interactions of lichen crust with separate minerals.

Quartz. The boundary between quartz grain and lichen encrustation is sharp. In several points small quartz fragments detached from the background are present in lichen thalli.

Feldspar. Hyphae of lichens penetrate feldspar grains. Penetrations are usually cleavage controlled. Locally cleavage planes are broadened and hyphae can be seen inside (Fig. 3). Numerous pits related to lichen penetration are present on feldspar sections. The depth of penetration is variable; it often reaches 4 mm. Lichen hyphae can be also penetrate inside weakened zones in feldspar related to sericitization (Fig. 3). Lichen thallus on feldspar contains irregular grain material of various chemical composition. Point chemical analyses indicate concentration of Ba, Al, Si, Ca (Fig. 4).

Biotite. Interactions between biotite and lichens are complex. Lichen penetrates deep into biotite crystals along cleavage (Fig. 5). The depth of penetration is related to the orientation of biotite. Biotite situated perpendicularly to the rock surface is penetrated significantly more deep than biotite oriented parallel to the surface. In extreme case lens-like remains of split biotite flakes are present inside lichen thallus. Significant chemical changes in biotite composition are related to the development of lichen community. Lowering of K content and increase of content Fe, Ti and Ca is typical of biotite flakes (Fig. 6, 7, 8). The content of Al is often also higher than in non-altered biotite. In lichen thallus in close vicinity of biotite Cl, Fe, Ti, Al and Si can be strongly concentrated (Fig. 8). Variable content of S can be also noted in lichen thalli.

DISCUSSION AND CONCLUSIONS

Presence of lichen on the surface of granite promotes both biomechanical processes (biogeophysical weathering) and biochemical processes (biogeochemical weathering).

Biomechanical processes are caused by penetration of hyphae and their intensity is related to the type of rock forming minerals (biotite>feldspar>quartz). Biomechanical processes result in fragmentation of the rock. Fragmentation can be stimulated by swelling and contraction of hyphae inside minerals related to ambient humidity and freeze-thaw processes. Expansion and contraction of thallus is also important among physical processes (Adamo & Violante 2000; Chen et al., 2000).

Biochemical processes are influenced by the activity of oxalic acid and so-called lichen acids (Chen et al., 2000). Dissolution of respiratory CO_2 in water contained in lichen thalli generates carbonic acid (Chen et al., 2000). The retention of moisture in the superficial layer of the rock by lichen layer enhances biochemical processes also. The net result of biochemical processes is related also to the reaction surface which increases with increasing degree of fragmentation and decreasing average fragments size. Biochemical processes cause migration of elements from minerals and accumulation in the thallus. Lowering of K content in biotite accompanied by increase of Al and Ca. Similar chemical changes in biotite were noted by Wierzchos and Ascaso (1996, 1998) and attributed to transformation of biotite to biotite/vermiculite interstatified mineral formation (Wierzchos & Ascaso 1998). Ti and Fe accumulations near transformed biotite are often observed. Accumulation of element in lichen thalli is variable and partly related to the chemical composition of minerals (e.g. Ba in vicinity of K-feldspar). Biotite is most subject to biochemical weathering processes among studied minerals. This phenomenon was noted in laboratory studies (Song & Huang 1988 *vide* Chen et al., 2000).

The protective role of lichen in granite weathering processes is difficult for evaluation. Binding of detached fragments beneath lichen thallus is clearly visible but it should be remembered that fragmentation is, at least partly, related to the development of lichens.

The presence of S in lichen encrustation can be related to adsorption of components of atmospheric pollution or but relatively low S content is typical of lichen from unpolluted areas.

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Fig. 1. Fragmented rock beneath lichen thallus (left). Numerous small grains accumulated near rock surface.

Fig. 2. Quartz, feldspar and biotite grains beneath lichen thallus. Biotite (Bt) penetrated and disrupted by hyphae (upper right corner).

Fig. 3. Cleavage and sericitization zones penetrated by hyphae.

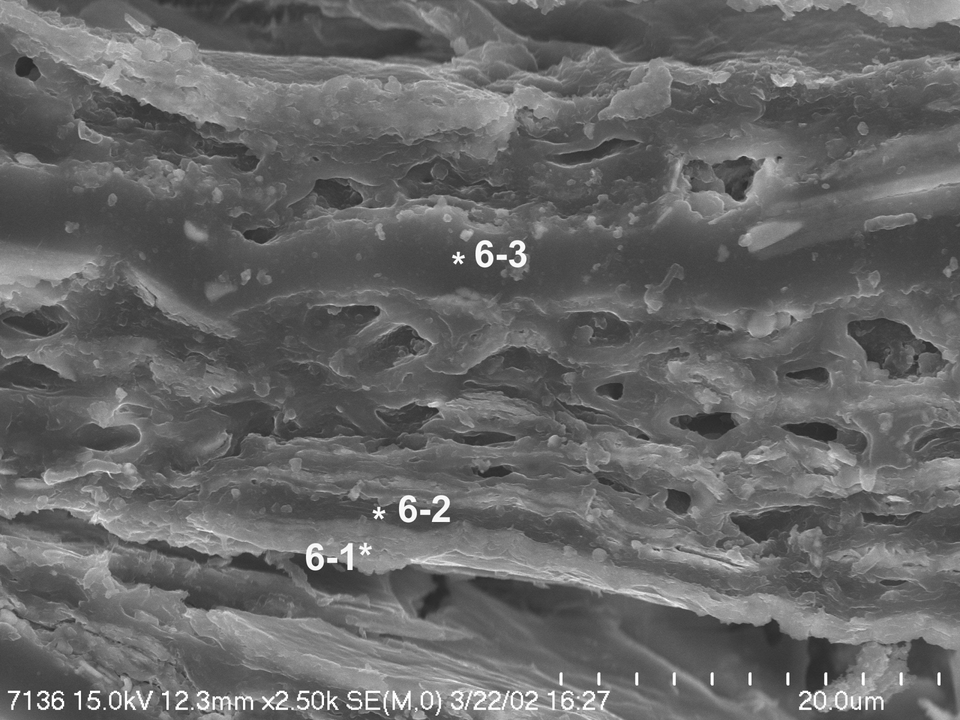
Fig. 4. Contact between lichen and sericitized biotite. Hyphae visible in “holes” related to sericitization. Variable concentrations of different elements in lichen. Point 3-1 – high concentration of Al, Ba, Si; point 3-2 – high concentration of Al and Si (Al>Si); medium concentration of Na and Ca; point 3-3 – high concentration of Si; medium concentration of Ca and Al.

Fig. 5. Biotite (Bt) beneath lichen thallus. Deep penetrations in biotite cleavage.

Fig. 6. Remains of biotite in lichen thallus. Grains (probably of secondary accumulation) of various composition. Point 5-1 – high concentration of Al, Si and Fe; medium concentration of Ti and Ca; point 5-2 – high concentration of Ti; lower amount of Al and Si.

Fig. 7. Lichen thallus with orientation inherited after biotite. Points 6-1 and 6-2 remains of biotite flakes – domination of Si; high concentration of Al, Fe, Ti; medium concentration of Mg and Ca, very low content of K; point 6-3 – Si, Al, and Cl beside C.

Fig. 8. Remains of biotite flakes dispersed in lichen thallus. Point 10-1 – biotite of relatively non-changed chemical composition, point 10-2 – thallus between biotite flakes – high concentration of Al and Si; Fe, Ca and S are present also.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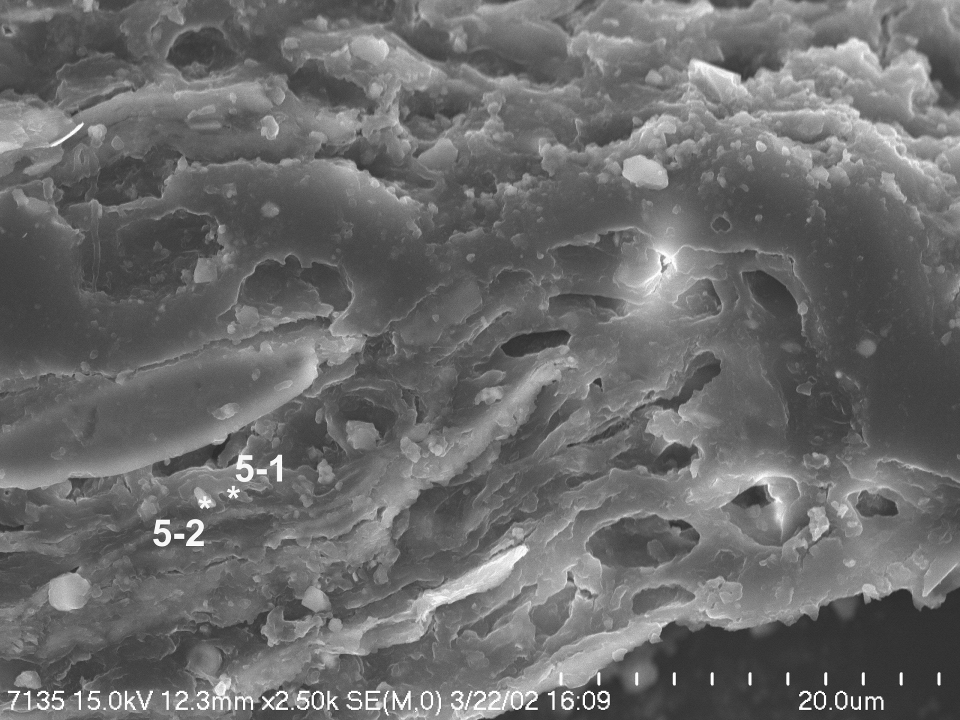
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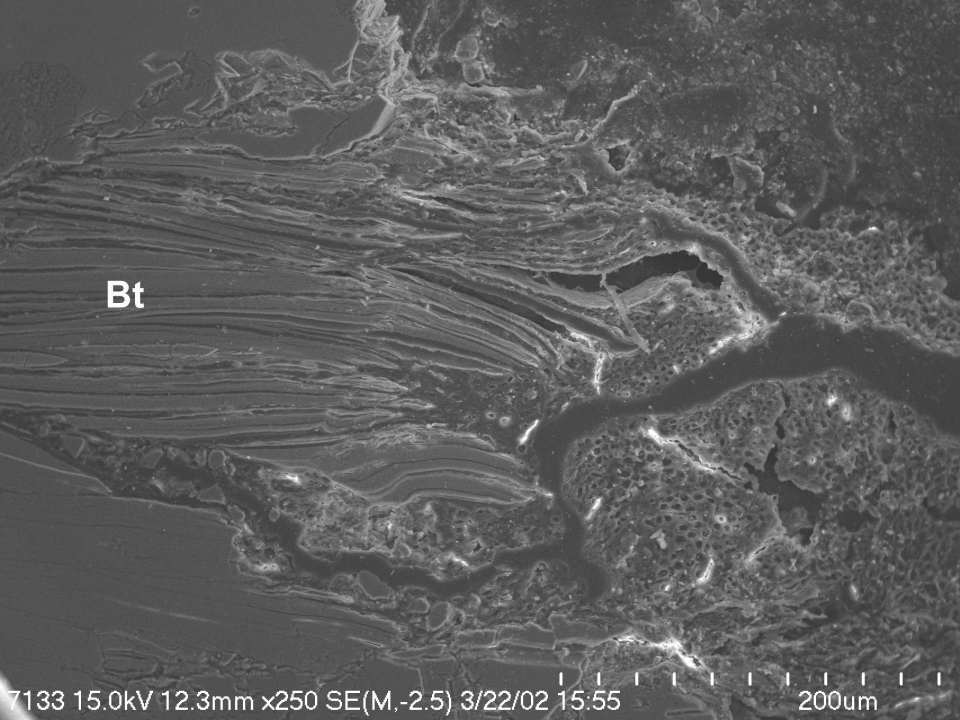
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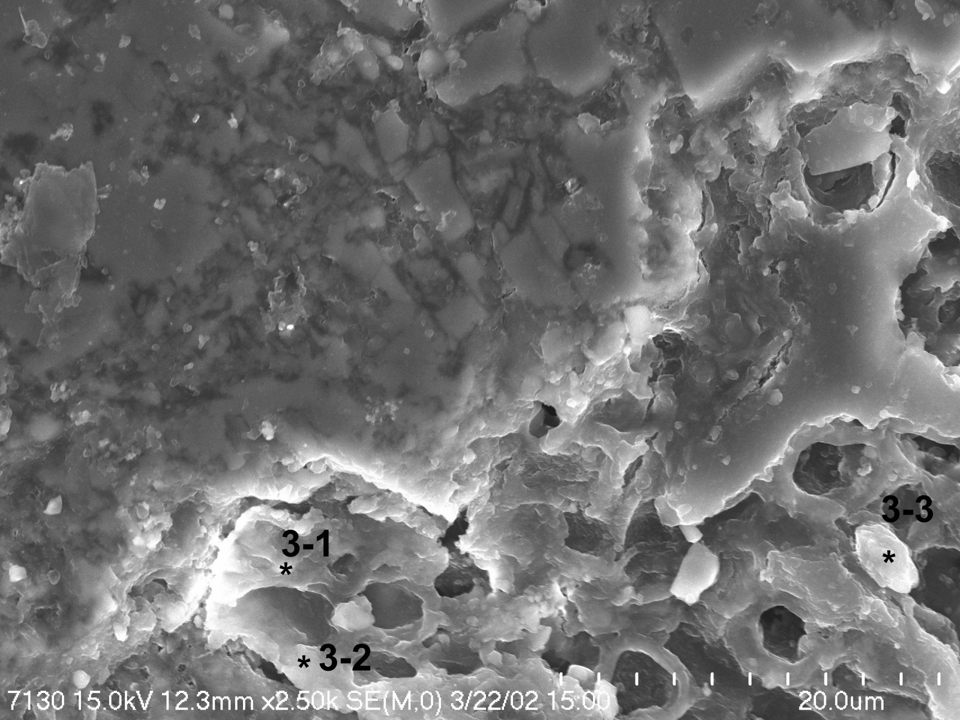
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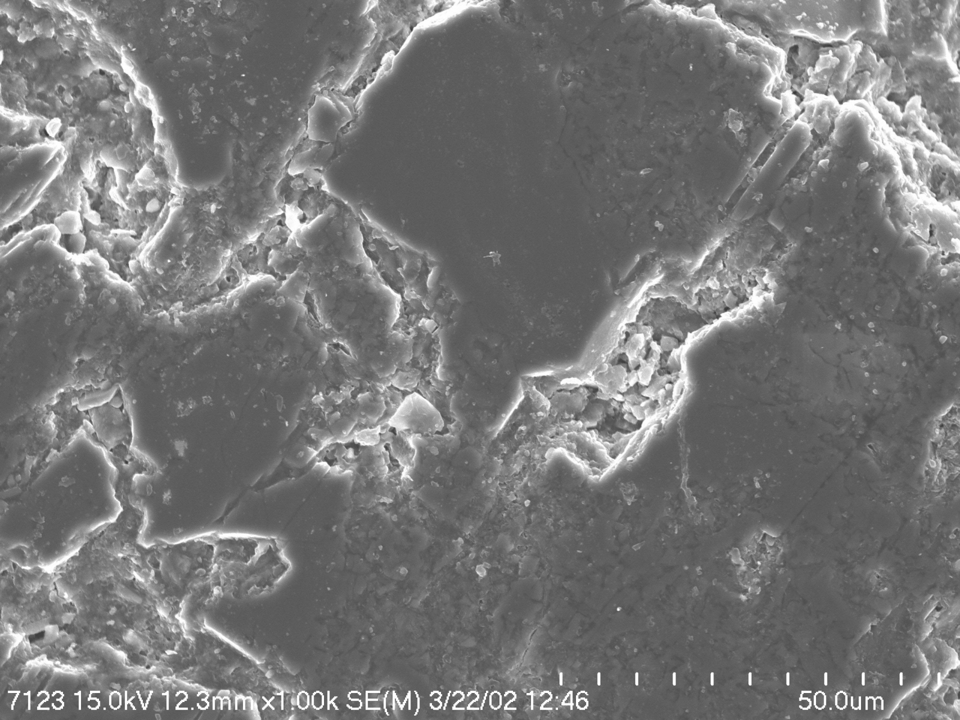
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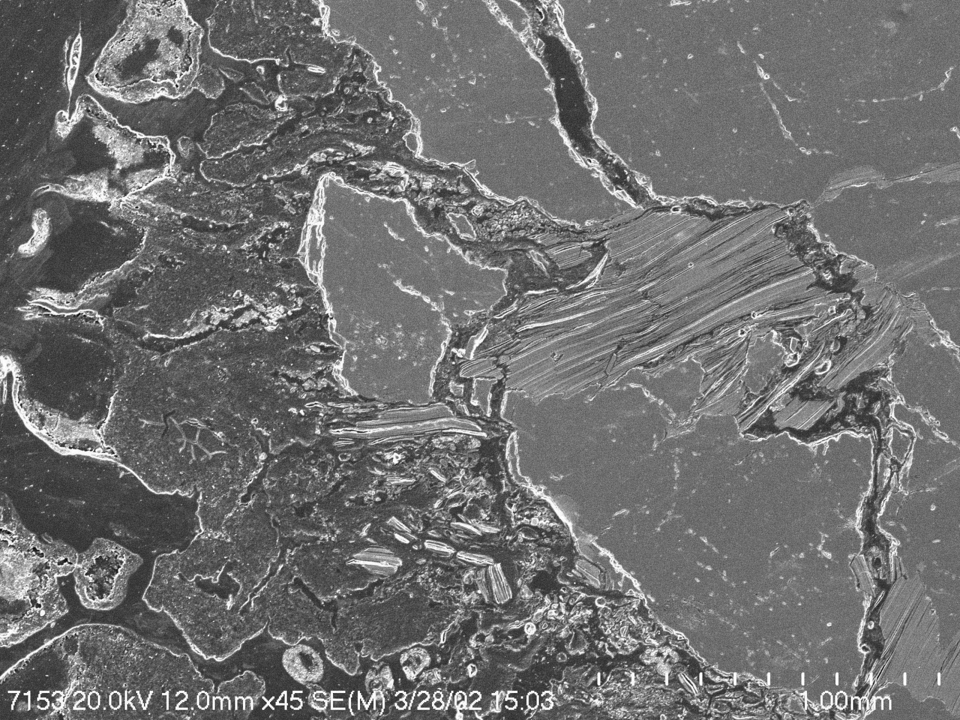
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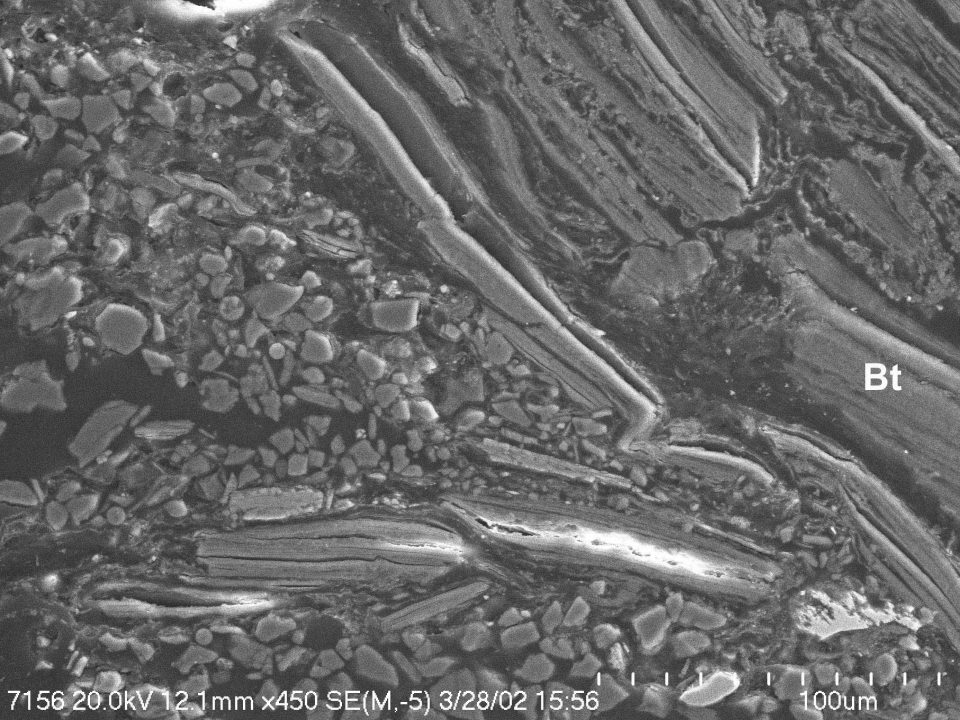
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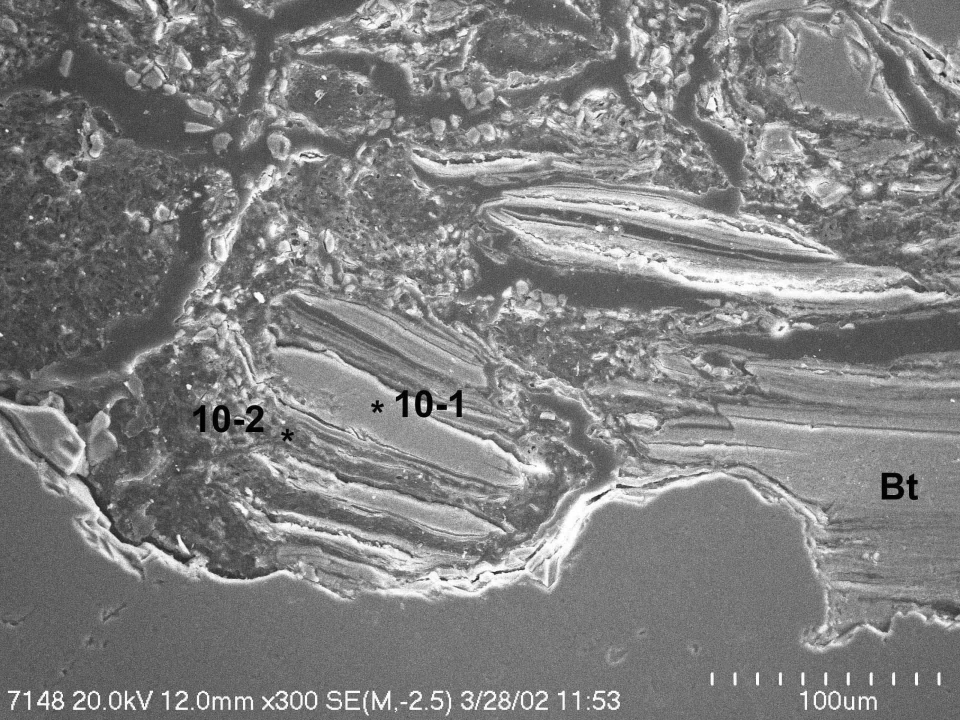
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