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Multiple length scale growth spirals on metamorphic graphite {001} surfaces studied by atomic force microscopy

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ABSTRACT

The microtopography of {001} surfaces on single crystals of graphite from a Neoproterozoic marble of the Swakop group, near Wlotzkas Baken, western Namibia, has been studied using differential interference contrast (DIC) microscopy and atomic force microscopy (AFM). A unique aspect of the observed surface microtopography is the presence of growth spirals and hillocks on three different length scales. The largest spirals are polygonized and can be seen without magnification. Steps on this feature are roughly 4 µm high and 90 µm apart. The second-order features are hexagonal growth hillocks with an average step height of 1.5 nm and total lateral dimensions of 5–40 µm. The apex of these hillocks coincides directly with the apex of reentrants in the macrosteps of the large spiral. Morphology suggests the formation of these polygonized hillocks by some mechanism other than simple spiral growth. We speculate that these features may be due to pinning of the macrostep by impurities and subsequent formation of the second-order hillocks. The third length-scale features are spirals found on terraces forming the vicinal faces of the second-order hillocks. These spirals have steps that are 6.7 Å high (unit-cell length along [001]) and an average step spacing of 900 Å. These double-layer steps also show some regions with partial step separation into 3.3 Å high monolayer steps. The observed microtopographic features give us insight into the conditions in, and mechanisms by which these graphite crystals formed during carbonate metamorphism. Crystal growth, unrestricted by the surrounding calcite, was from a fluid phase at low graphite supersaturation and was dominated by the spiral growth mechanism. Comparison with theoretical and simulation studies suggests a critical radius for two-dimensional nucleation on the (001) surface on the order of 100 Å.