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Fast migration of nano-fluids in calcite crystals

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The transport of supercritical fluids is a determining factor for several geological processes and fundamental in predicting natural resource accumulation and distribution. Calcite, ubiquitous in geological environments may contain supercritical CO_2 trapped under the form of fluid inclusions that may move through grain boundaries affecting the rock physical properties. However, despite the macroscopic evidence of this process it was not until now possible to characterize this process at the nano-scale because these observations were difficult. In this study, we report nanometer-scale observations on calcite crystal surfaces and demonstrate that stress with absence of visible deformation produces fluid leakage from fluid inclusions. Atomic Force Microscopy scanning experiments on freshly cleaved calcite crystals containing visible fluid inclusions revealed the spontaneous formation of nanometer-scale hillocks on flat crystal terraces in only a few minutes, without evidence of surface dissolution. The fact the hillocks formed on flat surface in a short time was unexpected and suggests deposition of material from the inner to the surface crystal through small-scale fluid migration. We estimated the rate of this fluid mobility is by several orders of magnitude higher than the diffusion rate through vacancies estimated in calcite crystals. Quantifying this fluid transport at the standard external conditions in the case of calcite, we show that mobility of these supercritical fluids through micro-pore and nano-pore spaces is in reality much higher than previously assumed using current predictive models.