Thermal spallation and fracturing of rocks produced by surface heating

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Heating of rock surface (e.g., flame heating) induces compressive stresses in the surface layer and tensile stresses of lower magnitude in the layer beneath. If the heating temperature is large enough (around 900 deg for shales), the compressive stresses initiate spallation produced by pre-existing cracks that and extensively grow parallel to the surface under compression. The extensive cracks separate thin layers from different parts of the heated surface which eventually buckle opening a new surface which starts being subjected to flame heating. Then the spallation process repeats itself producing a cavity of approximately cylindrical shape growing into the rock normal to the surface.

The presentation reports the results of tests on flame heating of shales, which demonstrate that the spallation process is accompanied by emergence of a large tensile fracture normal to the surface. In order to check whether the fracture can be produced by tensile thermal stresses induced in the layer situated under the compressed layer we conducted a series of finite element simulations of thermal stresses for different spallation depths (depths of the cavity). The modelling shows that: (1) as the spallation cavity deepens the magnitudes of maximum compressive and tensile stresses remain approximately the same except of two peaks at the spallation depths of about 6% and 30% of the diameter of the heating flame; (2) the magnitude of the maximum tensile stresses is about half of the compressive stress. Given that the spallation strength is about half of the UCS (e.g., [1]) and that the tensile strength is often up to an order of magnitude lower than the UCS, the induced tensile thermal stresses can be considered as sufficient to produce the tensile fracture.

The experiment and computer modelling suggest that the production of tensile fractures is an intrinsic feature of the spallation process. These results can assist in understanding large scale spallation-like processes in the Earth's crust and design rock cutting based on thermal spallation.