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Prediction of the macroscopic mechanical properties of carbonate from nano-indentation tests

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The major objective of this work is to estimate the macroscopic Young modulus and therefore the elastic wave velocities from local measurements of elastic moduli at the micro-meter scale.
To do so, we use nano-indentation technique, which consists in recording the penetration depth of an indenter of known geometry (Berkovitch type, triangular shaped in this study) and mechanical properties along with the applied load (i.e. loading/unloading stress-strain curves). The studied samples are microporous carbonates from the Gargano Murge region (southern Italy) made of nearly 100% calcite. Room-dried, small, irregular pieces, 5mm thick and with a polished surface of about 1 cm2 are used. For each probed sample, we acquire 2 perpendicular lines of 200 measurements, 10 um apart. The extraction of the mechanical properties for each measurement is achieved by using the unloading part of the stress-strain curves, assumed to be purely elastic, and by applying a continuum scale mechanical model in an isotropic medium to obtain the indentation modulus.
Then, the distribution function and the linear auto-correlation of the indentation modulus are derived from these data.
The numerical analysis consists of several steps.
First, random three dimensional media with a local indentation modulus M(x) which has the same distribution function and the same linear auto-correlation as the measured ones are generated at will starting from an arbitrary seed; x is the local position vector. This is achieved via a non linear transformation of normal correlated Gaussian fields.
Second, the field of local Young moduli E(x) is derived from the random field M(x), assuming that Poisson's ratio is a known constant.
Third, the macroscopic mechanical properties of the generated medium are obtained by means of a code based on lattice springs to integrate the elasticity equation with variable Lamé coefficients. The basic principles underlying this code will be briefly summarized.
Finally, the macroscopic properties are successfully compared with the measured ones at the core plug scale (2.5 cm in length and diameter).