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Nonlinearity, hysteresis, end-point memory, and congruence in sandstones

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Very low frequency stress-strain measurements on many rocks show definite and repeatable hysteresis loops. Much of the modeling of this behavior uses Preisach or Ising-like models adapted from models developed for magnetic systems which exhibit hysteresis. To date, the experimental data on many rocks showing end-point memory are noisy and only qualitative. The congruence property, in fact, has never been examined for rocks. Just how well does the behavior of a sandstone fit a Preisach model? To find the answer to this question, we performed a new set of careful stress-strain experiments on several sandstones to examine end-point memory (in detail) and also to see if the congruence property does indeed hold for these rocks. In addition we explored the dependence of measurement rate on the relaxation time of these rocks (the analog to magnetic aftereffect). For very slow measurement rates (low frequencies), hysteresis disappears, leaving only a simple nonlinear stress-strain curve.