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How many plates?

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The spacing of opening-mode fractures in layered materials, such as certain sedimentary rocks and laminated engineering materials, is often proportional to the thickness of fractured layers. Bai, Pollard & Gao (2000) investigated the full stress distribution between such fractures, from which they show that the spacing initially decreases as extensional strain increases in the direction perpendicular to the fractures. But at a certain ratio of spacing to layer thickness, no new fractures form and the additional strain is accommodated by further opening of existing fractures: the spacing then simply scales with layer thickness, which is called fracture saturation. Their conclusion is in marked contrast to existing theories of fracture, such as the stress-transfer theory, which predict that spacing should decrease with increasing strain ad infinitum. Here we show that the principle for 2D equal spaced fracture problem also applies to the 3D polygonal fracture problem. By using 3D mechanical modeling on a spherical shell model under interior expansion, we found that the modeled plate mosaic exactly follows the same principle that the size of formed plates is also proportional to the thickness of the fractured shell. By using a spherical shell model with isotropic, elastic two-layers, we numerically load the shell to fail under a quasistatistical, slowly increasing interior pressure in a displacement controlling manner (induced, e.g., by gradual thermal expansion). The fractures only occur in the surface layer. The value at which a particular element breaks is random, but fixed at the start of the fragmentation process (i.e., the disorder is quenched). The probability distribution (PD) of breakdown thresholds is a material property and is known from the start. We account for this local randomness by assigning to each element a failure threshold taken from a Weibull probability distribution (PD), with a parameter defines the degree of material homogeneity, called the homogeneity index. We use a three-dimensional finite element code named RFP (Rock Failure Process Analysis) to solve the problem. The modeling results show that, under conditions of uniform expansion force from inside the shell, the cracking pattern also follows a global scale law in terms of the thickness of the fractured layer. The numerical modeling demonstrates an important observation that, under conditions of uniform and layer-parallel tension induced by thermal expansion within the spherical shell, surface cracks spontaneously self-organize into quasi-hexagonal tessellations, following the mechanical principle that the hexagonal pattern relieves the greatest strain energy for the least work invested in nucleation and propagation of fractures. If this applies to the problems of Earth tessellations, called Platonics (Anderson, 2002), it implies that the thermal expanded Earth may breakup to form

plate-like network as a consequence of thermal-expansion induced rift rather than mantle convective or plutonic causes, and the plate size may be proportional to the thickness of lithosphere. This provides a new explanation on how the plate number should be, and whether there is a pattern in the plate mosaic, issues related to the optimal sizes and shapes of plates in terms of fracture spacing.