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Some Features of Cleavage Cracks in Rocks and Metals

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Abstract. The cracking of some rocks, namely granite, serpentinite and sandstone under tensile stress is examined in details. Brazilian testing or diametral compression, three points bending and explosion testing are used as the loading schemes in air at room temperature. Morphology of cracks in the model rocks are compared with cracks in silicon crystals, as the standard of a brittle crack, with cleavage cracks in iridium single crystals and with cracks in gallium-covered aluminum single crystals. The comparison of cracks between themselves has shown that there is additional channel for stress accommodation in the model rocks. This channel does not lead to transformation of a rock into a macroscopically ductile material, but it causes the arrest of the dangerous crack in it under tensile stress. Its influence causes transition from the brittle crack to the pore-like crack on the microscopic scale. The most probable mechanism of this transition is the dislocation emission from crack, which becomes possible in such a natural covalent solid as a rock due to Rehbinder's effect.

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REFERENCES

[1] J.A. Hudson, J.P. Harrison, *Engineering Rock Mechanics. An Introduction to the Principles*, Vol. 1, Pergamon Press, Amsterdam, 2000.
[2] J.F. Knott, *Fundamentals of fracture mechanics*, Butterworths, London, 1973.
[3] M. Kachanov, I. Sevostianov, *Micromechanics of materials, with applications,* Solid mechanics and its applications, vol. 249, Springer Nature, Heidelberg, 2018.
[4] Z. Briševac, T. Kujundžić, S. Čajić, *Current cognition of rock tensile strength testing by Brazilian test* // The Mining-Geology-Petroleum Engineering Bulletin, 2015, vol. 30, no. 2, pp. 101–114.
[5] K. Regenauer-Lieb, M. Veveakis, T. Poulet, F. Wellmann, A. Karrech, J. Liu, J. Hauser, C. Schrank, O. Gaede, F. Fusseis, M. Trefry, *Multiscale coupling and multiphysics approaches in earth sciences: Applications*, J. Coupled Syst. Multiscale Dyn., 2013, vol. 1, no 3, pp. 1–42.
[6] S.P. Lynch, S. Moutsos, *A Brief History of Fractography*, J. Fail. Anal. Prev., 2006, vol. 6, pp. 54-69.
[7] R.W.K. Honeycombe, *The plastic deformation of metals*, Edward Arnold, London, 1968.
[8] B.R. Lawn, B.J. Hockey, S.M. Wiederhorn, *Atomically sharp cracks in brittle solids: an electron microscopy study*, J. Mater. Sci., 1980, vol. 15, pp. 1207–1223.
[9] K. Higashida, N. Narita, M. Tanaka, T. Morikawa, Y. Miura, R. Onodera, *Crack tip dislocations in silicon characterized by high-voltage electron microscopy*, Philos. Mag. A, 2002, vol. 82, no. 17–18, pp. 3263–3274.
[10] D.K. Dewald, T.C. Lee, I.M. Robertson, H.K. Birnbaum, *Dislocation structures ahead of advancing cracks*, Scr. Metall., 1989, vol. 23, no. 8, pp. 1307–1312.
[11] P. Panfilov, *Brittle fracture of iridium. How this plastic metal cleaves?*, Rev. Adv. Mater. Technol., 2019, vol. 1, no. 1, pp. 27–45.
[12] M.H. Kamdar, *Embrittlement by liquid metals*, Prog. Mater. Sci., 1973, vol. 15, no. 4, pp. 289–374.
[13] S.P. Lynch, *Ductile and brittle crack growth: fractography, mechanisms and criteria*, Mater. Forum, 1988, vol. 11, pp. 268–283.
[14] P. Panfilov, Yu.L. Gagarin, *Evolution of transcrystalline cracks in gallium-covered aluminium crystals*, J. Mater. Sci. Lett., 1998, vol. 17, pp. 1765–1768.
[15] R.L. Lyles Jr., H.G.F. Wilsdorf, *Microcrack nucleation and fracture in silver crystals*, Acta Metall., 1975, vol. 23, no. 2, pp. 269–277.
[16] I.M. Robertson, H.K. Birnbaum, *An HVEM study of hydrogen effects on the deformation and fracture of nickel*, Acta Metall., 1986, vol. 34, no. 3, pp. 353–366.
[17] S.M. Ohr, *An electron-microscopy study of crack tip deformation and its impact on the dislocation theory of fracture*, Mater. Sci. Eng., 1985, vol. 72, no. 1, pp. 1–35.
[18] I.-H. Lin, R. Thomson, *Cleavage, dislocation emission, and shielding for cracks under general loading*, Acta Metall., 1986, vol. 34, no. 2, pp. 187–206.
[19] A.S. Argon, *Brittle to ductile transition in cleavage fracture*, Acta Metall., 1987, vol. 35, no. 1, pp. 185–196.
[20] M. Brede, P. Haasen, *The brittle-to-ductile transition in doped silicon as a model substance*, Acta Metall., 1988, vol. 36, no. 8, pp. 2003–2018.
[21] P.B. Hirsch, S.G. Roberts, J. Samuels, *The brittle-ductile transition in silicon. II. Interpretation,* Proc. Roy. Soc. Lond. A, 1989, vol. 421, no. 1860, pp. 25–53.
[22] Y.-H. Chiao, D.R. Clarke, *Direct observation of dislocation emission from crack tips in silicon at high temperatures*, Acta Metall., 1989, vol. 37, no. 1, pp. 203–219.
[23] P.A. Rehbinder, *Surface Phenomena in Disperse Systems. Physicochemical Mechanics*, Nauka, Moscow, 1979 (in Russian).