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Fractal Time-Temperature relations in magnetic nanoparticles and its application to kamacite remanence

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Neel's thermal activation theory of magnetic relaxation is a fundamental basis of rock and paleomagnetism. The theory tells us that a relaxation time arises from exponential function of magnetic moments (- $vJHc$) over their energy barriers (kT) for ensembles of an unique-size single domain magnetic particle, where v is a grain volume, J is a saturation magnetization, Hc is coercive force, k is Boltzman constant and T is temperature. Following Pullaiah et al. (1975), the time-temperature relation generates a well-known blocking diagram by using temperature dependence of J and Hc, describing that a remanence acquired during a time at a temperature can unblock during shorter heating step at higher temperature. However, it is wel known that natural rocks fail to match the Neel's theory even though the magnetic carrier is an ensemble of unique-size single domain particles. In fact, Pullaiah et al. (1975) and Jackson and Worm (2001) have shown an anomalously higher unlocking temperatures to remove thermoviscous components than Neel's theory expected. To overcome this problem, Walton (1980) proposed a theory based on a broad distribution of magnetic grain-size in natural rocks. His theory succeeded to explain the anomalous unblocking temperature by log-normal grain-size distribution, but it fails to derive Neel's theory. In this presentation, we propose an extended theory with fractal (power-law) grain-size distributions including a broad distribution of particle sizes by varying power indices (D) from unique (D=1) through log-normal (D=2) to fractal distribution (D=non-integer). Therefore, our theory explains both Neel's theory and Walton's one and also solves Pullaiah's anomalous result with D=3.5 for magnetite. Moreover, we apply our fractal theory to kamacite remanence by employing a temperature dependence of JHc for kamacite. Employing a new blocking diagram for kamacite, we compare our theory with a laboratory time-temperature experiment of kamacite remanence in shock melted veins and dusty olives in meteorite.