Gurland J & Plateau J. The mechanism of ductile rupture of metals containing inclusions. *Trans. ASM* 56:442-54, 1963.
[Brown University, Providence, RI and IRSID, St. Germain-en-Laye, France]

Ductile fracture was observed to proceed by (1) formation of voids at inclusions, (2) growth of voids, and (3) internal striction leading to failure. A phenomenological relation between inclusion characteristics and fracture ductility shows that the elongation to fracture depends primarily on the volume fraction of the inclusions. [The *SCI*® indicates that this paper has been cited in over 145 publications since 1963.]

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"At the time of the work described in the cited paper, I was a visiting scientist at IRSID, the French steel research institute in St. Germain-en-Laye, near Paris. I was on sabbatical leave from Brown University, with fellowship support from the National Science Foundation. I had joined IRSID because of the presence there of a group active in fracture research led by C. Crussard, J. Plateau, and G. Henry. Among other works, they had produced the most beautiful electron-microscope fractographs of dimples on fracture surfaces, clearly showing the close association of particles and voids. Some of these photomicrographs were later included in our paper.

"I worked closely with Plateau, my coauthor, now at Pechiney Co., Grenoble. Initially, we concentrated on the void nucleating process by observing the deformation *in situ* of steel specimens by optical microscopy. My suggestion to also include aluminum-silicon alloys at first encountered some dismay since only steels were supposed to be looked at in a steel research institute, but later was pursued with enthusiasm. The microscopy confirmed the cracking or decohesion of particles as the initial step of fracture. By dimensional analysis, a necessary condition of crack nucleation was formulated from the balance of stored elastic strain energy and crack surface energy. In hindsight, it is recognized now that further insight into the nucleation problem was hindered by the lack of knowledge then of the local plastic deformation associated with hard particles in a ductile matrix.

"A lucky break occurred in the middle of this work period by the appearance in a journal of the classic publication of Edelson and Baldwin[1] on the effect of second phases on the mechanical properties of alloys. Their work demonstrated clearly the predominant influence of particle and void volume fraction on fracture strain, and it stimulated my coauthor to formulate a phenomenological theory of void growth which led us to an expression for the failure criterion due to the overlap of expanding voids. The theoretical relation could be fitted to the Edelson and Baldwin data by means of an adjustable parameter of reasonable physical meaning.

"Edelson and Baldwin's compilation of experimental results eventually became the standard of comparison for the validation of numerous theoretical models published subsequently, of which our model had the dubious distinction of being the earliest, which may account partly for the high citation frequency.

"Since then, our experimental observations have been firmly incorporated into the body of literature describing the now generally recognized stages of ductile fracture, namely, nucleation, growth, and connection of voids. Our theoretical models, however, have given way to more rigorous treatments. The necessary condition of crack nucleation proved not to be a controlling factor in practice since it is almost always satisfied in real alloys at stresses well below the observed crack initiation stress.[2] Also, the description of void growth was appreciably advanced later by the application of continuum plasticity theory to the microscale, as, for instance, by McClintock[3] and Rice and Tracey.[4] A review of the subject matter may be found in reference 2."

1. **Edelson B I & Baldwin W M, Jr.** The effect of second phases on the mechanical properties of alloys. *Trans. ASM* 55:230-50, 1962.
[The *SCI* indicates that this paper has been cited in over 105 publications since 1962.]
2. **Argon A S, Im J & Safoglu R.** Cavity formation from inclusions in ductile fracture. *Met. Trans. A—Phys. Met. Mater. Sc.* 6:825-37, 1975.
3. **McClintock F A.** A criterion for ductile fracture by the growth of holes. *J. Appl. Mech.* 35:363-71, 1968.
4. **Rice J R & Tracey D M.** On the ductile enlargement of voids in triaxial stress fields. *J. Mech. Phys. Solids* 17:201-17, 1969.