J. Fluid Mech. (1973), *vol.* 61, *part* 1, *pp.* 206–208
Printed in Great Britain

REVIEWS

Dynamics of Fluids in Porous Media. By Jacob Bear. Elsevier, 1972. 764 pp. Dfl 94.00.

Fundamentals of Transport Phenomena in Porous Media. Elsevier, 1972. 392 pp. Dfl 65.00.

Differential Equations of Hydraulic Transients, Dispersion, and Ground Water Flow. By Wen-Hsiung Li. Prentice-Hall, 1972. 316 pp. £8.95.

Two of the books under review deal specifically with flow and transport in porous media and about half the third one is intended to bear on aspects of the same topic. A peculiarity of the topic is that it arises in so many branches of natural science and technology: a few years ago I enumerated 22 such contexts and doubtless the list can be extended. An irritating consequence is the, all too frequent, persistence within a particular field of a determined and contented ignorance of the literature and established concepts of the other fields. A partial remedy is to relate the topic to its primary bases in natural science: and, among these, fluid mechanics must loom largest. The conventional scale of discourse in fluid mechanics is, of course, the continuum (or Navier–Stokes) scale. A different scale of discourse, the macroscopic (or Darcy) scale, dominates porous-medium applications: discourse on this scale deals with physical quantities related to the averages of analogous quantities on the Navier–Stokes scale, the averages being taken over a fluid volume (or cross-section) large compared with that of the individual 'pore'. In my opinion the meaningful approach to studies of flow and transport in porous media involves constant interplay between the construction of useful theory on the Darcy scale and complementary critical analyses on the Navier–Stokes scale.

Jacob Bear, author of the first and most ambitious of these books, seems to go along with this view in his introduction when he writes, "The emphasis in this book is on understanding the microscopic phenomena occurring in porous media and on their macroscopic description". As one plunges more deeply into the book, however, one finds that the author has little feeling for how the flows he treats actually behave on the Navier–Stokes scale: his discussion of hydrodynamic dispersal starts from an unreal picture of this subtle and fascinating phenomenon as a simple branching process. The book is filled out with fashionable material which is irrelevant, if not positively misleading: chapter 4 has an exposition of Truesdell's dicta on the formulation of constitutive equations cheek-by-jowl with a doctrinaire exposition of Onsagerist 'thermodynamics of irreversible processes'. Juxtaposition scarcely reconciles the irreconcilable (cf. Lecture 7 of Truesdell's *Rational Thermodynamics*). In any case, attempts to apply to flow in porous media any formulation based primarily on chemical mixtures seem doomed to generate more heat than light: the realistic and productive point of departure for this topic has been the single component in an odd-shaped vessel. In due course, the author puts aside what has gone before and introduces Darcy's law through its experimental origins: and that serves as the real basis for treatment of specific problems in later parts of the book. Before getting on to the nitty-gritty, however, Bear backtracks into 15 pages devoted to discussion of alleged derivations of Darcy's law, though the thing worth saying about this is not said: namely that Darcy's law depends on two elements, the *hydrodynamic* one of the linearity of the Navier–Stokes equation in the limit of zero Reynolds number and the *statistical* one of 'sufficient homogeneity' of the medium to ensure the existence of appropriate averages on appropriate scales.

According to the author's introduction, he believes that his chapter on polyphase flow (including 'unsaturated flow') introduces a new concept, "that of an abrupt interface as an approximation replacing the actual transition zone that occurs between two fluids, whether miscible or immiscible". But this well-worn device goes back at least to Green and Ampt in 1911.

Professor Bear gives some 600 references, his choice being "those I think represent a more important point of view, are more appropriate from the educational point of view or are more readily available for the average reader". The consequences are not necessarily helpful and are sometimes odd: the authority for the statement that "one advantage of using the continuum approach is that any number of different continua may occupy the same space at the same time" turns out to be Rose, W., private communication, 1966; the reference for the "Curie–Prigogine symmetry principle" is simply Curie, P., *Oeuvres*, 1908; and the source of the revelation that when $\psi = \psi(x, t)$,

$$\frac{\partial x}{\partial t} = -\frac{\partial \psi}{\partial t}\frac{\partial x}{\partial \psi}$$

is an unpublished paper from the Agricultural Engineering Department of Colorado State University, 1962.

This last citation is just one of the mathematical infelicities in this superficially mathematical book. Another is the notation **1j** for a unit vector. (The results in combination with more conventional symbolism can be imagined.) A third is the perpetuation of the error that certain similarity solutions apply meaningfully in cylindrically and spherically symmetrical systems – a misconception I had thought laid to rest in 1966.

This book of nearly 800 pages is, unfortunately, suitable neither for its primary target, "advanced undergraduate students", nor for other novitiates who might imagine that its authority is proportional to its size. It will, however, be useful to seasoned campaigners armed with scepticism and a concern for the physics of the topic: even though they will regret its inadequate index, they will find in it material not otherwise conveniently to hand.

The second book of the trio involves this reviewer in something of a conflict of interest. I was a guest lecturer at the First International Symposium on Fundamentals of Transport Phenomena in Porous Media, organized by the Section on Flow through Porous Media of the International Association for Hydraulic Research, held at the Technion, Haifa, in February, 1969. This is the symposium volume. The papers are a fair sample of the state of the art in 1969. Eminently realistic and scholarly treatments were mixed in with some papers which served as paradigms of ignorance and incomprehension between fields (and nationalities) and others which sounded a retreat from relevant physics into sterile formalism (and a few which did both). They ranged from a sensible review of 'non-Darcian' flow by M. Kutilek to the long-expected first paper on magnetohydrodynamics in porous media. Howard Brenner gave a provocative guest lecture on flow in ordered media. (Unfortunately there was no preprint, nor does it appear in this book.) I remember it as a *good* symposium; the manifest shortcomings of many papers and the divergencies of viewpoint did not (as they might have done) paralyse discussion, but made it intense, stimulating, and potentially valuable. Regrettably, there has been no place in the symposium volume for either the content or the spirit of the discussions, and it seems that most authors have chosen to sit pat with their preprint texts. Nothing has been gained by the delay of nearly four years before hard-cover publication.

The text by Professor Li "is based on a course in applied mathematics and theoretical hydraulics for beginning graduate students of water-resources engineering". Within these limits, it is competent, readable, and well-organized. The chapter headings are: oscillation in surge tanks; variation of water quality in a stream; unsteady shallow-water flow; oscillations in shallow water; water hammer; diffusion and dispersion; flow of groundwater; two-dimensional seepage; solution for small perturbation. The claim that "sufficient explanation of the physics involved is included" may be valid for the hydraulic chapters, but it scarcely holds for the chapter on diffusion and dispersion. The various discussions of turbulent diffusion (in general and in shear flows), dispersion in porous media, dispersion in pipe and channel flow, and natural evaporation, are simplified and each is, in its own way, either deficient or erroneous. The unwary reader is likely to overestimate the physical and practical relevance of the mathematical formulations, which are, perforce, of a simplicity appropriate to the course in hand. Beyond these and other simplifications, one finds that really messy water-resource problems, such as those of flow and transport in unsaturated strata are (very properly) omitted. One therefore ponders the announcement on the dust jacket: "Treats all the important types of differential equation used in solving water resource problems". Perhaps true if one leans heavily enough on the word "types", but it comes perilously close to deceptive packaging.

J. R. PHILIP