Maurice Anthony BIOT (1905-1985)

Notice of main achievements

M.A. Biot, engineer, physicist and applied mathematician, was born in Belgium.
He obtained degrees in electrical engineering, mining engineering, philosophy as well as a D.Sc (1931) at the University of Louvain.
His work and original contribution cover an unusually broad range of science and technology including elasticity theory,soil mechanics, waves propagation and scatter, wing flutter, geophysics, seismology, thermodynamics, etc.

He went to Caltech were he received a Ph.D (**1932)** in Aeronautical Sciences:he was first student an the collaborateur of Th.von Kàrmàn, with whom he wrote a classic textbook : *Mathematical Methods in Engineering.*
His pioneering work (**1932)** on the response of structures to transcient disturbance led to the key concept of Response Spectrum Methods as universally applied tool in earthquake proof design**. (4-10 – 20 – 41 – 45**)

In the 1934-40 His theory of non linear elasticity accounting for the effect of Initial Stress, culminated in his monograph : M**echanics of Incremental Deformation (1965) .**

He taugh at Louvain, Harvard Columbia(were he taugh theoretical mechanics). This was interrupted in 1040) while he took leave tu assume responsabilities for research and teaching in aeroelasticity (OSRD).
He developed a three dimensional theory of aircraft flutter and introduced a matrix method and generalized coordonates in aeroelasticity . This led to widely applied design procedures on aircraft structure in order to prevent caatastrophic flutter.

As Lt.Commander US Navy Bureau of Aeronautics and member of Naval Technical Missions in Europe.

After the war he was brieflly on thr faculty of Brown University.

He became an independant scientific consultant for Shell Develop. Cornell Aeronautic Lab, sundry governement agencies, and Mobil research.

His interest in the mechanics of Porous Media dates back to 1940 with a fondamental paper in soil mechanics and return to the subject in the more general context of rock mechanics.23-41-...see I.Tolstoy 1992 « 21 papers by MA.Biot»

He developed an original theory for the reflection of electromagnetic and acoustic waves from a rough surface, showing that the effect of the roughness may be replaced by a smooth boundary condition **(73 – 74 – 77 – 78)**

In collaboration with Ivan Tolstoy he introduced a new approach tu pulse generated transcient waves based on a continuuous spectrum of normal coordinates (**70**) .

In 1957 he developed a mathemat theory of **Folding instability of stratified viscous and viscoelastic solids** and applied the result to explain the dominant features of geological structures. He brought to lignt thr phenomenon of internal buckling of a confined anisotropic of stratified medium under compressive stress and provided a quantitative analysis.
-72-_79-81-83-84-85-87-90-91-92-102-110-111—115-116-117-118-119-120-124-125-126--127-128-130-131-132-135-137-138-140-143-14-170-172-
***(gravity instability:79 - 87 – 111 – 126 - 127 – 130)**

Miscllenious :

Mrs Biot found the remarks and explanations amoung her husband papers after his death :

Outline of developments on Folding Instability

Initial paper ***(72)*** treated the general case of a layer as a thin plate for viscoelastic media, with purely viscous media as a particular case. In the viscoelastic case thermodynamic principles have an important bearing on the behavior. Concept of dominant wavelength.

The same theory based on the continuum theory instead of plate theory was treated for both non-adhesing layer ***(81)*** and adhesing layer ***(92).*** The adhesing layer based on plate theory was also analysed ***(83)***.

A survey of results and some preliminary experimental work is found ***(84 - 85)*** along with results for the effect of gravity and the case of continuous inhomogeneity. The influence of gravity was analysed in detail for the homogeneous layer ***(79)*** and the continuously in homogeneous case.

At this point experimental verification was needed through lab test as well as a confrontation of the theory with geological data and time scales. This was done in ***(90)*** and ***(91)***. This also included an analysis of the development of folds from an initial layer disturbance, showing the validity of the concept of dominant wavelength.

The theory of folding was found to be verified experimentally and relevant geologically.

A preliminary discussion was also given for the case of multilayers. The concept of wavelength selectivity was introduced. Attention was called to the phenomenon of internal buckling of a confined medium ***(102)***. This constitutes one of the important features of confined multilayers. Exact theories of stability were developed for multilayered continua ***110 -111-115 - 116 - 117.*** The case of folding of a porous layer was analyzed ***118***.

A theory of folding of multilayers based on a rigorous application of the Navier Stokes equation was developed in ***120***. The fluid undergoes finite strain as a function of time and an instable small perturbation is superposed.

A geologically important result is obtained in ***119*** and ***128***, when the internal buckling are considered of confined multilayers. Simple formula are derived for the folding wavelength which explain an important feature of geological structures.

Internal instability of a confined anisotropic viscoelastic continuum is analyzed in ***124***.

In ***128*** folding of multilayers under gravity is consider. The concept of transition wavelength is brought out, this separating the region when the folding is an overall bending, and the region when it is mainly shear.

In ***126*** folding with finite strain is considered and it is shown how a pinch effect (concentric folds) must be expected. Exact fluid mechanics is also applied to the single embedded layer and compared to plate theory. A gravity analogy is derived applicable to the effect of gravity. Gravity instability applicable to salt domes is treated in ***127 - 130*** in two and three dimension including a variable thickness of the overburden due to gradual sedimentation.

In **132** a more rigorous theory is developed for internal buckling of laminated media, and multilayers, which may be homogeneous for each layer or laminated.

A couple-stress analogy is developed.

Some folds of different wavelength may develop simultaneous since the corresponding amplification factors may be about the same.

The folding which dies out away from a fold is treated in **135**.

An elaborate theory of laminated continua is developed in **144**.

Initial stresses may include normal and shear stresses.

Exact and simplified approaches are considered for plates which are multilayered composites.

Thermodynamics :

In de middel of 1950 (first paper **54)** he developed a new approach to thr thermodynamics by introducing a general form of free energy as a key potential.Associated with new variational principles and Lagrangian type equation. As a by product of this work y developed a new approach to heat transfer wich avoid some physical inconsistencies of traditional methods. (**54-56-58-62-65-66-73-76-80-88-93-94-95-96-99-109-121-122-129-133-134)** he later gave a systematic presentation in his monograph

Variational Principles in Heat Transfer, (*A unified Lagrangian analysis of dissipative Phenomenon)*
(Oxford university Press, 1070)

N.B. Papers **54-56-62** introduced the Lagrangian method wich were to be the hallmarks of most other domains.

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A new revolutionary development in Thermodynamics has recently been initiated. It embodies a twofold aspecs.. One is represented by a new principle of virtual dissipation which generalized the classical d'Alembert's principle of mechanics to completely general non-linear irreversible thermodynamic.

The other is provided by an entirely new approach to the thermodynamics of open systems which introduces a new concept: the "Thermobaric Potential" leading to new definition of the chemical potential and avoids Gibbs paradox without recours to Nesset's principle or statistical mechanics.

Areas of application either potential or already initiated are indicated as follows.

A unified thermorehology of solids and fluids has been developed. The atmospheric dynamics or the biomedical problems of flow of body fluids.

A unified thermodynamic approach to the dynamics of fluid mixtures with thermomolecular d diffusion and mutual and self viscosities has also been developed. The method are entirely new and uses the new concept of thermobaric potential, which provides a powerful method of dealing with coupled flows of heat and matter. A particularly interesting aspect of the new approach, in addition to its improved generality over of the present results, is the possibility of taking into account vapour properties and phase changes.

A large area of application is the theory of coupled deformations, fluid and thermal flow, in porous solids including phase changes.

This includes the analysis of heat pipes and the systems analysis of heat pipes and the systems analysis of large and complex geothermal systems for power production.

The concept of thermobaric potentials also leads to a revolutionary approach to chemical thermodynamics. Enormous simplification of the thermodynamic treatment is achieved and new results have been obtained which are more general than those available in the classical literature. By incorporating these results in the fluid mechanics a potentially new and powerful approach is obtained for the analysis of combustion and shock waves including relaxation and diffusion effects.

Potential applications should also be mentioned in plasma physics, and radiation problems. This includes stability and non equilibrium problems.
The analysis of pulsating stars could be attacked in novel fashion.

In both method and spirit the program constitutes a basic departure from those of present schools. From a purely mathematical viewpoint it avoids formalistic and non elementary method while achieving results which go far beyond current developments.

In particular unified functional space concepts are used implicitly without recourses to existing ponderous definitions and method, using new and elementary procedures, based on the concept of resolution thereshold.

In **1975** : New thermodynamics (**Variational Reformulation of Irreversible process)** **:**
He derived a new chemical thermodynamics leading to the concept of intrinsic heat of reaction.These new theory

to obtain directly the field equations in systems were deformations are coupled to thermo molecular diffusion and chemical reactions..
On this basis he also extended in the theory of **Porous Media** including heat and mass transport with phase changes in absorption effects (**150-155-157-180-161)**

In **1984** he wrote a survey article wich can be seen as ageneralized and unified presentation of his most of his previous works on prestressed solid mechanics, poroelasticity and thermodynamics :

<u>**New Variational Lagrangian Irreversible Thermodynamics**</u>

Published in **Advance of Applied Mechanics (vol 24 pp. 1-91)- Academic Press. (paper nr 173)**

NB : **Remarks by Nady Biot.**

These new fundamental ideas are not yet fully understood. As he often said:

"It is obviously difficult to communicate new fundamental concepts which deviate from standard thinking..."

However useful deep insights and results will be extract from his reformulation of thermodynamics which he wrote up in 1984 survey article which can be seen as a generalized and unified presentation **of most of his previous work on presressed solid mechanics, poroelasticity and thermodynamics.**

New Variational- Lagrangian Irreversible Thermodynamics with
Application to Viscous Flow, Reaction-Diffusion and Solid Mechanics

(*Advance in Applied Mechanics, 24, pp.1 – 90, 1984.)*