DEPARTMENT OF
MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1973/61

LEGEND RECOMMENDATIONS
ECAFE TECTONIC MAP OF ASIA AND THE FAR EAST

by

H.F. Doutch

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SUMMARY

The author was seconded to Mineral Resources Section, ECAFE, Bangkok, as a consultant, to develop a set of recommendations for a Standard Legend for the proposed ECAFE Tectonic Map of Asia and the Far East, at 1:5 000 000.

The recommendations are given here in full. They were developed on an objective basis and are built up around a concept called Tectonic Stage, which is a packet of rocks separated from adjacent packets by unconformities, and differing from them in structural style and lithofacies.

INTRODUCTION

The compilation of the E.C.A.F.E. 1:5 000 000 Tectonic Map of Asia and the Far East has so far passed through two main stages. The first was an attempt to compile a map on similar principles to those of the map of Eurasia by Yanshin et al (1966); it proved impossible to complete this compilation. The second was the production of a model for the project, the model being a 1:5 000 000 Tectonic Map of Indonesia compiled by W. Hamilton, USGS, using plate tectonic principles. A consultative group meeting in Kuala Lumpur, Malaysia, in March 1972, decided that plate tectonic principles as used by Hamilton could not be applied to the whole of the map area. However, Hamilton's map will be published in due course.

At the meeting, in presenting the newly published 1:5 000 000 Tectonic Map of Australia and New Guinea (GSA, 1971), I emphasized its relative objectivity and urged the meeting to adopt a similar philosophy. Many other national tectonic maps, mostly in draft form, were presented at the meeting. They covered a wide range of standards and approaches, creating a very difficult compilation problem for the project Convenors, Drs Katili and Johannas of Indonesia.

By the end of the meeting it had not been possible to begin a Standard Legend to help national contributors to all compile their drafts in the same way, and it was decided to engage a consultant to develop a suitable 'general framework'. I was asked to do this work.

The Australian Departments of Foreign Affairs and National Development (as it was then) agreed to finance fares, salary, and allowances for two months work in Bangkok, Thailand, under the supervision of Mr Leo W. Stach, Chief, Mineral Resources Section, Natural Resources Division, E.C.A.F.E. During December 1972 and January 1973 the Recommendations presented here were developed.

In preparing them the following factors had to be taken into account:

(1) An ECAFE Working Party of Senior Geologists at its eighth Session at Bandung in 1970 had drawn up tentative specifications for the map in terms of Platforms, Fold Belts, etc., apparently desiring to conform as closely as possible to the principles proposed by the Commission for the Geological Map of the World for use for the legend of the Tectonic Map of the World.

ECAFE is preparing the Tectonic Map of Asia and the Far East partly as a contribution to the world map, and the Working Party's specifications will have to be re-evaluated when the compilation reaches its interpretative stage.

(2) The Co-ordinators and Associate Co-ordinators proposed for controlling the project are of international professional standing, and a set of recommendations to them about the legend will be more appropriate and better received than a set of cut-and-dried specifications.

(3) There exist two published tectonic maps, both at 1:5 000 000 scale (that of the ECAFE map), using concepts still favoured by many geologists. They are the Tectonic Map of Eurasia (Yanshin et al., 1966), and an atlas of tectonic map sheets of the USSR, China and Mongolia, chiefly by Terman and Alverson, USGS, (Alverson, et al., 1967).

There is no point in the ECAFE map being a replica of either of these. Unhappily, however, they are one of the major sources of information on China and Mongolia.

(4) The Kuala Lumpur meeting suggested that the ECAFE 1:5 000 000 Geological Map of Asia and the Far East should be a prime reference document with regard to the distribution of geologic units.

(5) There are problems about obtaining contributions from some countries, involving such things as government policies, co-ordination difficulties, the various level of experience of compilers, and the schools of tectonic philosophy they belong to. Therefore an objective and straight forward set of legend recommendations will have the best chance of general acceptance and successful application.

(6) The sooner the map is finished the better, with respect to production and budget scheduling. It is desirable that legend recommendations be comprehensive and easy to follow so that no time is wasted by compilers waiting for clarification of legend items.

(7) The Kuala Lumpur meeting considered a proposal by Dr J. Stöcklin of Iran, now an Associate Co-ordinator, that the ECAFE map be based on some unit like the various types of Structural Stages of published maps. Mr I. Konyshev, in charge of production of regional maps by the Mineral Resources Section, expressed a similar view.

Having accepted these factors as constraints, the recommendations presented here more or less suggested themselves. The most difficult problem has been to maintain objectivity and consistency, and to ignore well established tectonic hypotheses such as geosyncline and plate tectonic hypotheses.

The recommendations are based on a conscious attempt to keep separate the operations of classification from those of terminology, and on the proposition that classification in terms of all the known attributes of rock bodies will be more generally useful than selecting critical criteria which will eventually restrict tectonic interpretation.

The basic unit suggested, the Tectonic Stage, differs fundamentally from most of the Russian type Structural Stages. These seem to lean heavily on 'formational analysis', the interpretation, often presented subjectively, of what rock types and assemblages are thought to represent tectonically. Had the consultative group meeting wanted to use this philosophy there would have been great difficulty because of the lack of data - it is not very successful on Yanshin et al's map. Tectonic Stage is a more flexible concept, being essentially described in terms of structural style.

The recommendations permit the legend to evolve with the map. To take them further would be to impinge on the prerogatives of creativity of the contributors.

During the development of the recommendations I benefited greatly from discussions with Mr I. Konyshev, of ECAFE, Dr D.K. Ray, Geological Survey of India, Dr Tin Aye, Mineral Development Corporation, Burma, Professor Ba Than Haq, Arts and Science University, Rangoon, Burma, Dr J. Stöcklin, Geological Survey of Iran and the Co-ordinators, Dr Katili, Indonesian Institute of Sciences (LIPI) and Dr Johannas, Geological Survey of Indonesia.

ECAFE Tectonic Map of Asia and the Far East

Legend Recommendations.

PART 1 - INTRODUCTION

These recommendations have been examined by the Co-ordinators and Associate Co-ordinators of the map project and contain amendments they suggested.

This is not a final and complete Standard Legend. The variety of schools of thought about tectonics reflected in the map compilations sent to ECAFE so far makes it almost impossible to construct a Standard Legend to which they can all be adapted.

So, after considering the purpose of the map, it seemed advisable to compile it in two main stages. These recommendations should make it possible for all contributors to produce, as a first stage, similar compilations which can be joined together with a minimum of difficulty. The second stage will be the adoption of a mutually acceptable interpretative theory which can be satisfactorily applied to the completed first stage compilation of the whole map area, and which will be the basis of the final Legend.

The first stage compilation will have as its fundamental unit the Tectonic Stage. This is described in detail later; briefly it is a packet of rocks separated from adjacent packets by unconformities and differing from them in, most importantly, structural style, and secondarily, lithofacies.

Purpose of map:

1. Dissemination of data on regional structure and tectonics, in part to inform, in part to stimulate research into tectonics and metallogenesis.

2. To serve as a base or guide for metallogenic maps.

Therefore data should be made obvious in the Legend, if not also on the map, and the terms used for them should be as objective as they can be.

General aspects of data handling

Objectivity is essential during all operations when preparing the first stage compilation. Natural relationships in time and space should be clearly shown without the compiler being influenced by favoured tectonic theory. If this is done carefully there should be few problems of joining contributions at national boundaries.

At the same time, efforts should be made to show data important to any current tectonic theory in a clearcut fasion.

It is very desirable that map symbols should give a combined representation of both contemporaneous tectonism and crustal evolution. Such a system cannot be fully developed for the first compilation stage, in which the proper use of letter symbols will be critical for this purpose.

At all stages the terminology used should not be of a kind that causes the map user's thinking to be severely channelled, nor his hypothesis making to be restricted, but enough data should be shown to prevent him from making false hypotheses unnecessarily. Therefore for the first stage compilation non-genetic, morphological, descriptive, objective terminology only should be used.

At all stages it is desirable that the map together with its legend should be self-sufficient and self-justifying, able to be used and understood even if Explanatory Notes are not available to the map-user.

To this end the level of tectonic generalization must be watched carefully. (It is unwise to show a great amount of detail just because it is known; nevertheless, when in doubt it is better to err on the side of too much detail rather than too little.)

Some data problems

Mineral deposits: data on mineral deposits should not be used, but omitting geology relevant to deposits should be avoided. This is to prevent the occurrence of circular reasoning when the map is used to investigate metallogenesis.

Geophysical data: gravity contours should be available; structural form lines based on magnetic or seismic work may be useful; earthquake epicentres, their depths, and contours on Benioff Zones may be feasible.

Igneous rocks: can probably only be classified by lithology and Tectonic Stage association.

Metamorphism: for the first stage compilation the most objective treatment is to map them by lithology and Tectonic Stage association, as will be done for igneous rocks. Interpretation of temperature/pressure properties and relationships properly belongs to the final legend stage.

Sea-bottom tectonics: little sea-bottom stratigraphy is known, so that it may only prove possible to use structural symbols for folds and faults etc, and structural contours/form lines or isopachs. These will be superimposed on layer colouring representing shelf, slope and abyssal plain.

PART 2 - TECTONIC STAGE - DEFINITION

Most of the tectonic maps of various parts of Asia held by ECAFE in Bangkok use a tectonic unit called the Structural Stage, although it is not certain that it is the same thing for each map. Tectonic Stage is recommended as the fundamental tectonic unit for the ECAFE map, and compilers should understand it to be defined as follows:

Following Dr Stöcklin's (Iran) concept of Structural Stage, the Tectonic Stage in its simplest form is a rock succession between two unconformities. In more detail, it is a set of sequences of rocks which may or may not have been produced by, added to, or altered by thermal events (igneous and/or metamorphic), or structurally deformed.

As an extreme case, igneous intrusions which occur at about the same time as folding, uplift, and resultant unconformity, may produce the youngest rocks (perhaps the only rocks) in a Tectonic Stage.

Using this definition, Tectonic Stages may be recognized in any tectonic setting, although this becomes difficult in highly metamorphosed terrains. However, unconformities have been mapped in most Precambrian igneous/metamorphic Platform/Craton Complexes. There are other cases where discontinuities between domains of contrasting structural style and lithofacies and different ages are not clearly identifiable as unconformities, and these must be analysed as objectively as possible with regard to what follows.

The distinction between a significant regional unconformity and an unimportant local unconformity depends partly on map scale, partly (in the final stage of the map's preparation) on feedback from the final synthetic theory adopted, but mainly on the requirement that the unconformity should usefully separate rock successions with contrasting structural styles and trends, and contrasting lithological facies, preferably in combination.

'Structural Style' covers the total effect of deformation on the rock succession it differentiates, including any metamorphism accompanying or resulting from the deformation, and any penecontemporaneous igneous events.

Thus map boundaries to Tectonic Stages are mainly traces of natural unconformities, not conceptual lines derived from theory. Unconformities resulting from glaciation or changes in sea level unrelated to tectonism should not be Stage boundaries.

The rock succession of the Tectonic Stage represents one or more types of tectonism, while the unconformity at the top of the Stage also represents tectonism of one sort or another. The nature of the tectonism should be described in the legend. Descriptions should also differentiate between these tectonic events and those that occur later and modify the already existing Tectonic Stage; however, the colour of an area on the map could well be unique and represent its complete tectonic history, including its contemporaneous associations (see below).

But, strictly speaking, the time span of a Tectonic Stage extends only from the time of emplacement of its oldest deposits on the lower unconformity surface to the time of the youngest known tectonic event associated with its upper unconformity.

As the time spans of Tectonic Stages can be of greatly differing lengths, few Stages will be likely to correlate exactly. Nevertheless it is of as much interest to know what kinds of tectonism are contemporaneous as it is to know the patterns of evolutionary tectonics; therefore the showing of contemporaneity and evolutionary patterns should be attempted by a combination of the appropriate symbols for each, preferably resulting in a unique colour and letter symbol, but in any case avoiding difficulties for draftsman and printer.

It is unlikely that substages bounded by unconformities will be erected (except conceptually, which is undesirable). But it may be desirable to subdivide stages with respect to zones of metamorphism, volcanism, structural variations, etc.

Nearly all the tectonic maps held by ECAFE use the terms Massif, Platform, Platform Cover, Geosyncline, and Orogeny, and they may well be used in the final Standard Legend when they have been defined for Asia by examining the data collected into Tectonic Stages for the first stage compilation. Of course, there may be better natural groups into which the various types of Tectonic Stage fall. Similarly, rather than conceptually deciding to emphasize any particular type of Tectonic Stage (e.g. one associated with climactic orogeny), it would be better to emphasize the natural relations between Stages (this is more useful than 'climactic' orogeny for understanding metallogenesis, for instance).

Other current hypotheses in tectonics - world-wide orogenies, geosynclinal development, plate tectonics - are better explored by this map than accepted as a means of compartmenting Tectonic Stages. The data relevant to such hypotheses should be symbolized as clearly as possible.

Two examples of recognition of Tectonic Stages follow.

PART 3 - TECTONIC STAGE - RECOGNITION AND COMPILATION

1. General organization of Tectonic Stages, and naming them

Without departing from objectivity a compiler can use the criteria by which he differentiated Tectonic Stages in his area to arrange them in a sequence ranging from undeformed stages at one of its extremes to greatly deformed at the other.

The smaller the area being analysed the more imperfect, incomplete, uneven will the sequence be. Gaps, weaknesses, discontinuities in his sequence can be used by the compiler as natural class boundaries for the purpose of grouping Tectonic Stages together usefully.

Many of these style type groups will correspond with natural morphological, physiographic, features and can take their names. Many names have been used in Asia, but as an analysis of 'fold belt' names used on various maps will show, there is no international unanimity about them yet (see Appendix 1.).

This is partly due to the variety of philosophies and theories that names are associated with or derive from. The first complete compilation of the ECAFE Tectonic Map should avoid such names and associations, and only terms of a geographical and morphological nature should be used - e.g. Yunnan-Malaya Fold (Mountain) Belt.

It is not possible to foresee a complete range of such terms. Generally they will fall into three basic categories - Basement, Fold Belts, and Cover. These terms are probably best used in this sort of way: Basement (suggested letter symbol B): The term is often appropriate for the oldest Tectonic Stage in an area, but as this may also be an old fold belt the compiler has a choice of terms. Both could be used in combination. The term could be qualified specifically as a metamorphic complex, fold belt inlier, etc.; interpretative variations such as median massif, ancient nucleus, with connotations of particular tectonic philosophies, should be avoided. In particular, the term 'Platform' should not be used for the time being. Time term qualifiers - e.g., Precambrian Basement - should also be avoided.

Fold Belts (suggested letter symbol F): Geographical and morphological fold mountain belts are the type feature for the term, but deformation (including plutonism) rather than physiography is the critical criterion. The terms geosyncline, orogene, etc. are related to the secondary criterion of lithofacies, are interpretative, and should be avoided for the time being, as should time term qualifiers (e.g. 'Mesozoic' Fold Belt).
Cover (suggested letter symbol C): Morphologically any relatively undeformed rock body overlying a more deformed one is cover to it. Therefore Fold Belts can be regarded as a special case of Cover. However, this use of the term is hardly likely to be very helpful.

But the term Cover can be more useful than in its restricted form 'Platform Cover' (a term which should not be used for the time being). As well as applying to undeformed or very slightly deformed rock bodies overlying basements, it can also be applied, without resorting to lithofacies interpretations, to cover rocks overlying fold belts. In some cases fold belt cover is deformed, in others not. Eventually, when the whole map is interpreted according to whatever philosophies or theories are found mutually acceptable, fold belt cover may be found to be more appropriately regarded as fold belt stage(s) in some cases, cover stage(s) in others, or perhaps as transitional between fold belt and cover conditions.

The tectonic map of northern Thailand with this Document shows fold belt cover stages with the letter symbol C. Diagram 2, in which Thailand is considered in a wider context, shows the older cover stages of the same area with the transitional or dual classification letter symbol F/C. A similar objective re-evaluation of national contributions in the wider context of the completed first stage compilation of the whole map will probably be necessary.

The term basin should be used with great care. Time term qualifiers should be avoided.

Together with these objective, major, group terms it will be appropriate to use the internationally familiar structural terms for smaller features - grabens, horsts, folds, faults of various sorts. Terms such as anteclise, syneclise, dalle, aulacogene, should be used with care. Terms associated with geosynclinal or other theories, such as foredeep, foreland basin, should not be used for the time being.

2. <u>Examples of recognition and analysis of Tectonic Stages</u>

A. Tectonic Map of Northern Thailand, Scale 1:1 000 000.

Included is a tectonic map of Northern Thailand prepared in a fairly mechanical way from the geological map by Baum et al. (1970), and from conclusions in the report it accompanies. The diagram from the report, annotated with the symbols used on the tectonic map, is included here as Diagram 1; it is the basis for recognition and analysis of the Tectonic Stages in the area.

On Diagram 1 there are more unconformities than have been used for identifying Tectonic Stages. Baum's text discussion does not clarify the significance of those not used, but they do not seem to be associated with changes in structural style, although they are associated with lithological changes. If this 1:1 000 000 map is regarded as a preliminary step in compiling a 1:5 000 000 scale tectonic map, such unconformities can probably be disregarded, particularly if they are of local occurrence only.

DIAGRAM 1

TECTONIC STAGES IN NORTHERN THAILAND

AGE	LITHOLOGY	IGNEOUS ACTIVITY	TECTONIC MAP
HOLOCENE PLEISTOCENE	gravel, sand, clay	basalt	not shown ← $_{T}C_{4}$
TERTIARY	sand or silt (sandstone - siltstone), gravel (conglomerate), clay with intercalations of lignite, bituminous shale, freshwater - limestone, calcareous tufa		$_{T}C_{3}$
? CRETACEOUS to JURASSIC	J_5 red argillaceous and sandy deposits J_4 greenish-grey or red arcosic sandstone, shale and siltstone J_3 conglomerate, red sandstone, with intercalations of siltstone and shale, locally marine limestone	granite (γ_3)	/// & $_{T}\gamma$ $_{J\text{-}K}C_{2}$
TRIASSIC: NORIAN to SKYTHIAN	locally limestone, marine, grey shale, sandy shale, sandstone, partly in red facies with conglomerate J_1 conglomerate with intercalations of siltstone and shale limestone, cherty limestone, chert, shale shale, sandy shale, arcosic sandstone, greywacke conglomerate, sandstone (locally red), laterally replaced by finer clastic facies	J_2 andesite to rhyolite with respective tuffs and agglomerates granite (γ_2) locally andesite, tuff	$_{Tr\text{-}J}C_{1}$ $_{Tr}\gamma$
PERMIAN: UPPER	marine sandy shale, sandstone, with intercalations of chert	locally intermediate to acid volcanics with tuffs	$_{Cu\text{-}Tr}F_{2}$
PERMIAN: MIDDLE to LOWER	fusulinid limestone, laterally replaced by clastic sediments, locally transgressive; in place reaching down into uppermost Carboniferous		
CARBONIFEROUS: UPPER	marine clastic series (sandstone, conglomerate), predominantly in red facies, with limestone intercalations, shale	locally tuff volcanic to subvolcanic sequence of predominantly intermediate to basic rocks, partly as amphibolite	$_{Cu}\pi$
CARBONIFEROUS: LOWER	chert, shale, sandy shale sandstone, greywacke, shale, with subordinate limestone intercalations	granite (γ_1)	$_{Cl}\gamma$
DEVONIAN	partly: throughout calcareous facies with shale intercalations mainly: fine clastic with chert or limestone intercalations, sandy shale, graptolite bearing black shale and chert		$_{Є\text{-}Cl}F_{1}$
SILURIAN	partly: calcareous to marly facies mainly: sandstone and sandy slate, with minor amounts of chert and slate (or phyllite)		
ORDOVICIAN	limestone and/or various amounts of slate and sandy slate (or phyllite)		
CAMBRIAN to LOWERMOST ORDOVICIAN	quartzite and/or sandy slate (or phyllite) locally conglomerate		
PRECAMBRIAN	paragneiss with marble intercalations	granite (?)	$_{pЄ}B$

after Baum et al (1970).

There is no detailed information in Baum et al's report bearing on structural style, so that the systematics advocated in this Document can only be applied in a broad way. It has to be assumed that the older Stages are, the more deformed they are.

In such cases the critical criterion used in recognizing unconformities as significant (and hence the Tectonic Stages they separate as meaningful) is their association with thermal events. This of course implies that Stages C_1 and C_3 on the tectonic map have dubious validity, and indeed on a 1:5 000 000 scale map Stages C_1 and C_2 could be combined, as could Stages C_3 and C_4.

The legend for the map goes a long way towards fulfilling the requirement that the map be self-justifying and self-sufficient. The terms 'Indosinides', etc., in inverted commas are of course not objective. Please regard them as intended, as cross-references to other peoples' ideas; overall, the general organization of the legend can be said to be objective being based on morphology. The terms Cover, Fold Belts, and Basement are labels for the style type groups of Tectonic Stages. The proper terms to use should of course derive from this explanation of the compilation; no genetic speculations are made here, so as to avoid influencing the development of the ECAFE map, and the terms used are specified to have purely objective morphological meanings for the purpose of this exercise. National contributors using terms in this way should explain what they have done much as I have done.

There remain to be discussed only a few cartographic points.

The tectonic map does not follow accurately the geological boundaries of Baum et al.'s original. Indeed, the Stage boundaries would probably require more generalization for a 1:5 000 000 scale map. (I regret that some small areas of some Stages have been omitted by mistake.) Stratigraphic time subscripts of letter symbols are general enough for a smaller scale map but are unsuitable in the context of the whole map (see discussion in example B, following). It would be possible at 1:1 000 000 scale to show stratigraphic boundaries and symbols faintly, thus giving a better idea of the spatial development of each Stage. One or two pattern symbols differ from those recommended in Document 3 and elsewhere, a regrettable example of personal inertia.

B. Tectonic Stage diagram for Burma, Thailand, Indochina and Malaya

A relatively small area like northern Thailand is simple to analyse in terms of Tectonic Stages, from which a map can be compiled. The next step is to consider how the report by Baum et al. relates to the report 'Geology of Thailand' by the Department of Mineral Resources, Bangkok (1969), and to their 1:1 000 000 geological map of the whole of Thailand. At the same time one can consider how both in turn relate to reviews such as:

(a) Geology of Laos, Cambodia, South Viet-Nam and the Eastern part of Thailand - A Review (Workman, 1972).

(b) Outline of the Geological Evolution of Malaya (Burton, 1972).

(c) Geological map of the Malay Peninsula (Gobbett, 1972).

(d) Tectonics and Metallogenic Provinces of Burma (U Ba Than Haq, 1972).

(e) Maps of offshore 'Tertiary' basins (various sources).

(f) Geological Map of Asia and the Far East, and its explanatory brochure published by ECAFE in 1971.

(g) Tectonic Map of Eurasia (Yanshin et al., 1966).

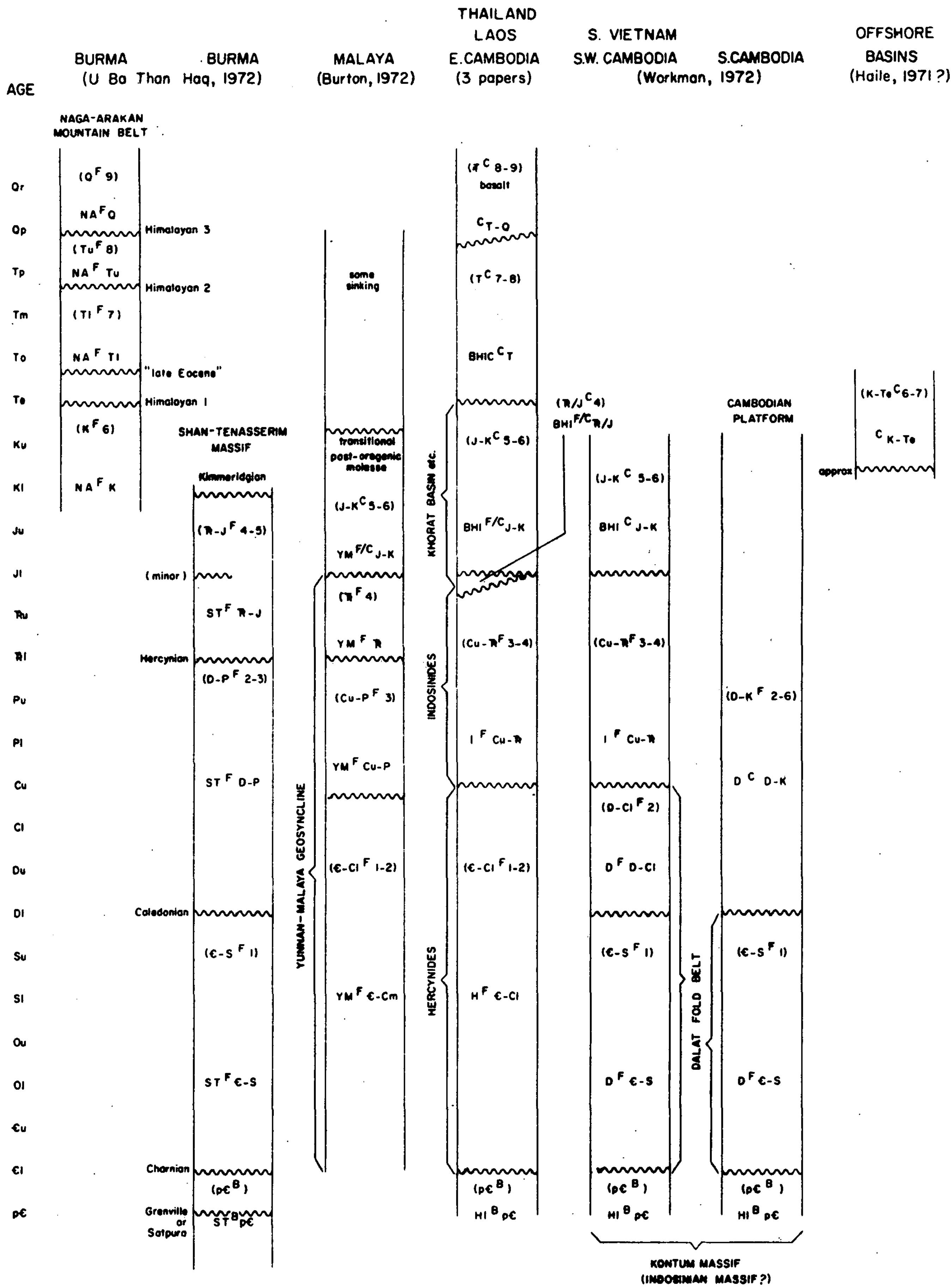
(This amounts to a grab sample, but is most of what was readily available at the time of the exercise).

The two reports on Thailand appear to be in harmony for the purpose of the exercise, and in general to agree with the review by Workman. His review then becomes the key to the analysis of Tectonic Stages throughout Indochina and Thailand. The papers and maps on Malaya and Burma do not critically compare similarities and differences with other countries, so it is to be expected that their national boundaries will in some cases be Stage boundaries. This may or may not turn out to be important in terms of any genetic theory finally adopted, but compilation will present no problem if done mechanically, as on the ECAFE geological map.

Diagram 2 is the result of the analysis, and it points up aspects of the problems of grouping Tectonic Stages internationally, and of plotting the spatial boundaries to them on a map.

DIAGRAM 2

TECTONIC STAGES IN INDOCHINA, BURMA AND MALAYA.



The oldest Stages probably differ in stratigraphic time ranges, and in Burma, if not elsewhere, there may be more than one Precambrian Stage. But in general there are very few data available about either the original ages of the rocks in any of them, or when they were deformed or affected by thermal events. For a 1:5 000 000 map the oldest Stages are all most simply treated as being of the same type, for which one appropriate morphological term, for use until development of a genetic theory, is Basement (B). This group is made up of such named tectonic features as the Kontum Massif.

In the Phanerozoic two types of Tectonic Stage appear to be present:

(a) Older rock bodies which have been folded and faulted, and also affected over wide areas by thermal events; and

(b) Younger rock bodies which have been affected only by broad warping and minor faulting; thermal events were restricted to a few small granite intrusions and to undeformed basalt flows.

As in northern Thailand, the older type morphologically occurs as Fold Belts (F). The younger may have originally been deposited as a cover continuous from over Basement rocks to over Fold Belt rocks, and locally appear to reflect structurally the degree of continuing mobility of the domains underlying them.

However, this comment departs from the objectivity of previous discussion, and while it suggests that these younger rock bodies could be conveniently labelled Cover in a morphological sense, it may be more objective to divide them into two sub-types. Less deformed domains overlying Basement rocks are morphologically Basement Cover. More deformed domains overlying Fold Belt rocks may be regarded either as Fold Belt Stages or Fold Belt Cover, and the alternatives are shown on Diagram 2 as C and F/C. At this point I recommend comparing what is recommended here with what appears on the Tectonic Map of Eurasia.

Contemporaneity of the Stages is clear enough from Diagram 2, but time symbolization on the map now becomes more complex than it was on the map of northern Thailand. Colour symbolization of time will depend partly on trying to distinguish tectonic features by colour, partly on trying to combine with this colour overprints appropriate to stratigraphic time. Letter symbolization could include Stage number as used on the map of northern Thailand, and as shown in brackets on Diagram 2 (note the changes introduced by the fold belts of Burma). But obviously Stage numbering would be difficult and probably confusing, if not useless, if attempted for the whole of Asia and the Far East.

The best system of letter symbols for Stages can only be devised after the whole map has been compiled. On Diagram 2 a system has been used that may work for the whole area. It consists of a letter indicating the Stage group type, with subscripts for feature name and the stratigraphic time limits of the Stage. For example, the 'Indosinian Fold Belt' (if it survives the compiler) is shown as I^{F} Cu–₸R, ^{F} being the Stage group type, and subscript I standing for Indosinian. One might even make the subscript YMI if the term Yunnan-Malaysian Geosyncline survives.

3. Conclusions

It would be a pity if the complexities of the problem resulted in more attention being paid to 'fold belts' than other types of Tectonic Stage. For most of the purposes for which the map will be used, particularly for investigating metallogenesis, a well balanced presentation of tectonic evolution is a necessity.

However, it should be clear by now that it is for the compiler to decide how to group Tectonic Stages together in his area and what to call them. For example, Workman recognizes two sets of fold belts in his review area - the Hercynides and the Indosinides. Burton disucsses the rocks of the equivalent time interval in adjacent Malaya in terms of the history of the Yunnan - Malaya Geosyncline. What is the most appropriate way of naming and discussing the group of tectonic stages found to be equivalent to Workman's fold belts and Burton's geosyncline for the purposes of the ECAFE map is for the compilers to decide.

It will be important for a compiler to state concisely, in the form of a table or diagram, what seem to be the different types and groups of Tectonic Stage in his area, and to show how they are related in time and space. Any system of terminology the compiler develops from the one outlined above should be restricted for the time being to the analytical notes accompanying the map he sends to his Associate Co-ordinator, and feedback from it should not be used to re-organize the originally observed time and space relationships.

PART 4 - FIRST COMPILATION LEGEND RECOMMENDATIONS

It is not possible at this stage to draw up a rough legend draft for Fold Belts. It is not so difficult to prepare one for Basement and Cover, although what follows will inevitably be much amended for Phanerozoic Stages at least, as compilation progresses.

BASEMENT

The oldest rocks and the oldest Tectonic Stages in most regions - crystalline, folded, igneous and/or metamorphic complexes (in due course may be classified as Ancient Platforms, Massifs, Basements, Nucleii, etc.)

B	age of oldest contrasting Stage in region unknown. If possible indicate Era by subscript (e.g. p€, pPz, pM etc.)
B_A	metamorphism and folding circa 2600 m.y. Includes all older rocks and events, and those possibly as young as 2300 m.y.
B_{Ptl}	folding circa 2000 m.y. Rocks as old as 2400 m.y.
B_{Ptm_1}	folding circa 1600 m.y. Rocks as old as 2000 m.y., possibly as young as 1400 m.y.
B_{Ptm_2}	folding circa 1200 m.y. Rocks as young as 900 m.y.
B_{Pzl}	oldest contrasting Stage in region in age range early Palaeozoic (Indosinian Massif?)
B_{Pzm}	oldest contrasting Stage in region in age range mid Palaeozoic.
B_{Pzu}	oldest contrasting Stage in region in age range late Palaeozoic (W. Burma, Indonesia?)
B_M	oldest contrasting Stage in region in age range Mesozoic (W. Iran)

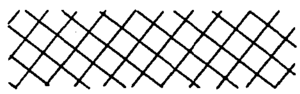
For longer or more exact time intervals the letter symbol subscripts could indicate the appropriate stratigraphic time range. If it is found desirable to differentiate between the various types of oldest Stages the letter symbol B used could be changed to whatever is appropriate and possible.

COVER

I	Background colour:	
	Neutral grey	Age of folded basement etc. below cover unknown
	Colour	Age of basement known - pale shade of basement outcrop colour
II	Examples of Tectonic Stages	
	C_A	Archaean - early Precambrian (pre-Vindhyan)
	$C_{Ꝑtu}$	Late Precambrian (Vindhyan V^CBtu, Sinian $_SC_Ꝑ$tu)
	$^{S}C_{Pzl}$	Early Palaeozoic (Cambrian - Silurian of India, etc.)
	C_{Pzm}	Mid Palaeozoic (early cover on Indosinian Massif)
	C_{Pz-M}	Late Palaeozoic - Early Mesozoic (Gondwana $_GC_{Pz-M}$)
	C_M	Mesozoic
	C_{Czl}	Palaeogene
	C_{Czu}	Neogene/Quaternary

Subscript time ranges should be as exact as possible.
Stage margins on map should be coloured lines only where they are the unconformities at the base of the Stage rock succession. For inliers letter symbols will have to suffice. See notes on Tectonic Stage symbols for more details. Show structural contours where possible in appropriate event colour. Alternatively or in addition show thickness ranges by layer tinting.

III Cover deformation, reactivation of basement, etc.:



cross hatching, as on 1:2 500 000 Tectonic Map of Europe.
Grey = time of deformation unknown.
Colour= time of deformation.

TECTONIC STAGE SYMBOLS, GENERAL

1. Boundary: Coloured margin inside black line, thinner and broken where concealed, thinner and queried where inferred. Colour to represent time span of rock interval above the unconformity the boundary represents. (NB: although the oldest Tectonic Stage of a region will have no lower Stage boundary, it will still be easily recognizable - see below).

2. Time range of Stage: indicated by colour of line representing lower unconformity, <u>and</u> a paler tint of the same colour for the Stage's outcrop area. A still paler tint could be used for concealed parts of a stage where younger stages lying above can be made 'transparent' (See Stages C_1 to C_4 on tectonic map of northern Thailand).

The time range should also be shown as part of the letter symbol, as a subscript - see Diagram 2, etc.

3. Colour Scheme: In order to best avoid for the compiler the associations attached to most colours by virtue of international usage for stratigraphic intervals or tectonic domains, the following scheme is suggested <u>for the first compilation only</u>. As it is the whole of the visual spectrum in its natural order there should be no difficulty selecting a Stage colour appropriate to its time range.

Cainozoic	Mesozoic	U. Palaeozoic	M. Palaeozoic	L. Palaeozoic	U. Proterozoic	M. Proterozoi
bluish & very dark reds	bright reds	orange brownish reds	yellow & ochres	yellow green	blue green green	blue

L. Proterozoic	Archaean
violet	indigo

purple

4. Structures:

(a) folds, faults, etc., known to have formed during the time span of a Tectonic Stage could be shown on the draft in the colour of that Stage's boundary line.

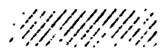
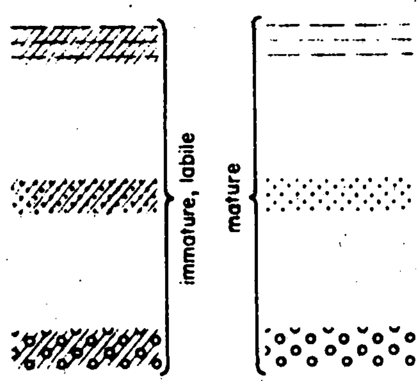
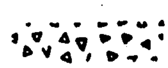
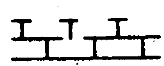
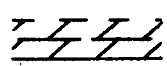
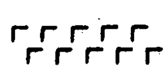
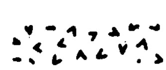
(b) if the age of a structure in unknown, show it in black.

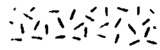
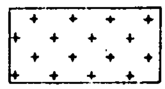
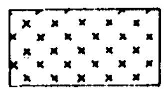
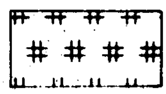
(c) the most factual evidence available to permit grouping of stages into evolutionary sequences are structures which develop over a time interval greater than that of one Stage. It seems desirable that such structures should be shown on the draft in some unique way. For the time being the design is left to you.

(d) the symbols for relatively small structures should be those in common use internationally. For large and/or unusual structures - large grabens, horsts, domes - superimpose on the Tectonic Stages involved some pattern of your onw choice.

(e) Well known names for large and small structures should preferably be shown on a separate structural sketch if time permits - otherwise put them on the draft.

5. Lithological facies: for speed in making draft compilations most of the provisional symbols below can be confined to a narrow band just inside the Stage boundary (see tectonic map of northern Thailand). They could be the same colour as the Stage boundary. If it seems useful to do so in any particular case, smaller symbols of lighter line weight could be used where the Stage is concealed. Symbols for igneous intrusives and for the oldest Stage in a region should entirely fill such areas on the map.

ROCK		LETTER SYMBOL
Undifferentiated		
Lutite		
Arenite		
Rudite		
Turbidite		
Evaporite		
Carbonate, calcareous		
dolomitic		
Carbonaceous		
Siliceous		
Acid tuff		
Intermediate or basic tuff		

ROCK		LETTER SYMBOL
Acid lava		
Intermediate or basic lava		
Acid plutonics and hypabyssals		γ (S^{γ}, M^{γ} etc)
Intermediate to basic plutonics and hypabyssals		δ
Basic to ultrabasic plutonics		β
Serpentinite		π
Mélange		
Metamorphics in general		
Granulites		
Glaucophane schists		

Symbols can be mixed as desired and extras invented

Comments:

(a) The term 'turbidite' is defined in the A.G.I. Glossary of Geology as a turbidity current deposit. As the term refers to fabric more that to grain size, the symbol suggested here does not properly belong with most of the others. Care should be taken to use it objectively, avoiding implication of any genetic theories.

(b) The term 'melange' is defined in the same glossary as a mixture or complex of rocks, and has been used for chaotic breccias and conglomerates. It is included here as a result of discussions and decisions at meetings in Kuala Lumpur in 1972, at which Dr Hamilton explained his usage of it on his plate-tectonic map of Indonesia. This term and symbol, too, do not properly belong with the others, being in Hamilton's sense subjective and interpretative. It is included for use by those who wish to indicate what they think belongs in such a category, but it is of course as much a special case as ophiolite, flysch, molasse, etc, which relate to geosynclinal theory.

(c) Extra symbols may be necessary for such things as undifferentiated volcanics and important lithological types of metamorphic rocks. Please invent your own.

However, this list of symbols should cover all lithological types for objective classification purposes. Specific rock types - e.g., adamellite, dacite, chlorite schist, diamictite etc. etc. - can be named in the legend of the first stage compilation, and decisions made then about inventing special symbols for special cases for the final map. Therefore, please avoid as far as possible inventing extra symbols.

(d) Symbolization of igneous rocks should be similar in all tectonic settings: pattern symbol shows rock type, pattern colour shows stratigraphic age of emplacement, background colour shows Tectonic Stage; letter symbol denotes rock type, stratigraphic age and tectonic setting.

In the legend, 'boxes' will not be arranged according to Tectonic Stages, but according to the granite ages, as indicated in the letter symbols applied on granite areas on the map, and by the colour chosen for the pattern symbol. There will be no background colour in the boxes; instead, the Tectonic Stages to which granites of a particular age belong will be listed beside the box.

Symbolization of metamorphic rocks follows the same rules as for igneous rocks.

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Appendix 1

Analysis of Fold Belt Nomenclature in Asia and the Far East

The list is in three parts. The first deals with the area covered by Diagram 2, the second with China and Mongolia, and the third with Iran and Japan.

It is possible to recommend tectonic feature names for the ECAFE tectonic map in the case of the first list only.

For China and Mongolia the three sets of tectonic feature names on the second list correspond to three different sets of map principles and tectonic philosophies. The USGS names are more appropriate at this stage for the ECAFE map. However, the Chinese "tiwa" concept may be acceptable and useful when described objectively. Therefore Li's list of names for tiwa features cannot be dismissed for the moment as inappropriate (note that not all Li's tiwa regions are included in the second list).

As tiwa regions include fold belts, basement and cover, a Standard Legend cannot be designed until the concept has been either accepted or rejected.

The third list shows that it will not be possible to prepare a consistent legend based on a single hierarchy of tectonic feature terms unless compilers are able to supply appropriate names. Yanshin uses a mixture of structural/tectonic names and morphotectonic terms, and something similar will probably develop for the ECAFE map.

The recognition and naming of 'fold-belts' for the ECAFE map will begin with the compilers, after which co-ordinators and editors will finalize the terminology.

PART 1

NAMES OF TECTONIC FEATURES ('FOLD BELTS') IN BURMA, THAILAND, INDOCHINA AND MALAYA

Workman (1972)	Yanshin et al (1966)	Kudriavtsev et al (1969)	Ba Than Haq (1972)	Alverson et al (1967)	Burton (1972)	possible morpho-tectonic terms for ECAFE map.
	Regions of Cenozoic (Kamchatka) tectogenisis	West Burma fold systems	Morphotectonic units (regions of Himalayan folding)			
	Arakan Foredeep		Arakan Coastal lowland			Arakan Basin
	Arakan Uplift		Naga - Arakan Mountain Belt			Naga - Arakan Fold Belt
	Irrawaddy Downwarp		Central Irrawaddy Lowland			Irrawaddy Basin
Indosinides: Annamitic, N.Laos, Luang-Prabang, Petchaburi, Chantaburi, Kampot & Saravane fold belts, and Sillon cochinchinois	Regions of Mesozoic and Hercynian folding of Indochina etc.	East Burma, Thai-Malaya, Central Indochina and North Vietnam folded zones.	(regions of Kimmeridgean, Hercynian, Caledonian and Precambrian folding)	geosynclinal rocks deformed by Mesozoic orogenies, and basement rocks weakly to strongly metamorphosed by lower Palaeozoic and Archaean orogenies		
	North Vietnam Folded Zone			Indochina Fold System: Mekong		Indochina Fold Belts
Hereynides: Dalat fold belt, and a number of massifs	Laos-Vietnam Folded Zone			and		
	Burma-Malaya Folded Zone		Shan-Tenasserim Massif	Salween Fold Belts	Yunnan-Malaya Geosyncline	Yunnan-Malaya Fold Belt
	Example of problem of naming 'fold belts'. Compilers should suggest most appropriate names to associate Co-ordinators. Small feature names such as those used by Workman are probably in appropriate for a 1:5,000,000 scale map.					possible Precambrian fold belts in Burma, northern Thailand & North Vietnam.

PART 2

CHINA AND MONGOLIA

Li (1971)	Alverson et al (1967)	Yanshin (ed.-1966)
	TIBETAN PLATFORM:	
Kailas Geosyncline region	Nyenchhan Thanglha Basin	Southern Tibet Anticlinorium
Tibet-Yunnan tiwa region	Chan Thang Platform	Tibetan Massif
	INDOCHINA FOLD SYSTEM:	
	Mekong Fold Belt	Lutsiang Anticlinorium
	Salween Fold Belt	
Himalaya geosyncline region	ALPINE HIMALAYAN FOLD SYSTEM	Himalayan Mega-anticlinorium
	CENTRAL CHINA FOLD SYSTEM:	
Astin tiwa region	Astin Tagh Uplift	Altin Tagh Anticlinorium
Kunlun geosyncline region	Central Kunlun Fold Belt	Central Kunlun Synclinorium
	Sunlung Shan Fold Belt	Norther Kunlun Anticlinorium
	Pamir Fold Belt	Aguil-Lokzun Synclinorium
	N.Pamir-Muztagh Fold Belt	
Kantse geosyncline region	Eastern Kunlun Fold Belt	Sikan Synclinorium
		Batan Anticlinorium
Tsaidam tiwa region	Tsaidam Basin	Tsaidam Basin
Chilien tiwa region	Nan Shan Fold Belt	Tsilyanshan Anticlinoria and Synclinoria
Chiling tiwa region	Tsin ling Fold Belt	Tsinling Synclinorium
South part of Honan-Shantung tiwa	Ta-Pieh Shan Uplift	
part of Yangtze tiwa region	Yangtze Fold Belt	
South-east area of South China tiwa region	CATHAYSIAN FOLD SYSTEM:	Shiansi-Kan Synclinorium
	Kusi-Hsiang-Kan Fold Belt	
	Chiang-Nan Uplift	Chiannan Anticline
	Kwangtung-Fukien Fold Belt	Katasian Anticlinorium
	East China Volcanic Area	

PART 2 (continued)

Li (1971)	Alverson et al (1967)	Yanshin (ed.-1966)
	CENTRAL ASIAN FOLD SYSTEM:	
Tien Shan tiwa region	Tien Shan Fold Belt	(various smaller feature names)
	Pet Shan Uplift	
Dzungaria tiwa region	Dzungarian Stable Block	
Chiern tiwa region	Dzungarian Fold Belt	
Altai tiwa region	Altai Fold Belt	
Sungari-Liao platform	Sung-Liao Basin	Sunliao Syneclise
part of Kirim-Shantung tiwa region	Bureya Basin	Zey-Bureya Syneclise
	Bureya Stable Block	Hengan-Bureya Massif
	Wan-Ta Fold Belt	
part of Hingan-Mongolia tiwa region	Hangayn-Henteyn Crystalline Belt	Hangan-Henten Synclinorium
	Gobi Fold Belt and Basins	Gobi Synclinorium East Mongolian Synclinorium
	Onon-Arguin Fold Belt	Onon-Gazemur Synclinorium
	Hsing-An Volcanic Area	
	SOUTH SIBERIAN FOLD SYSTEM:	
	Vitim Yablonovyy Crystalline Belt	Djedin-Prebaikalian Synclinorium
	part of Sayan-Tuva Fold Belt	Mongolian Altai Anticlinorium

Part 3

IRAN

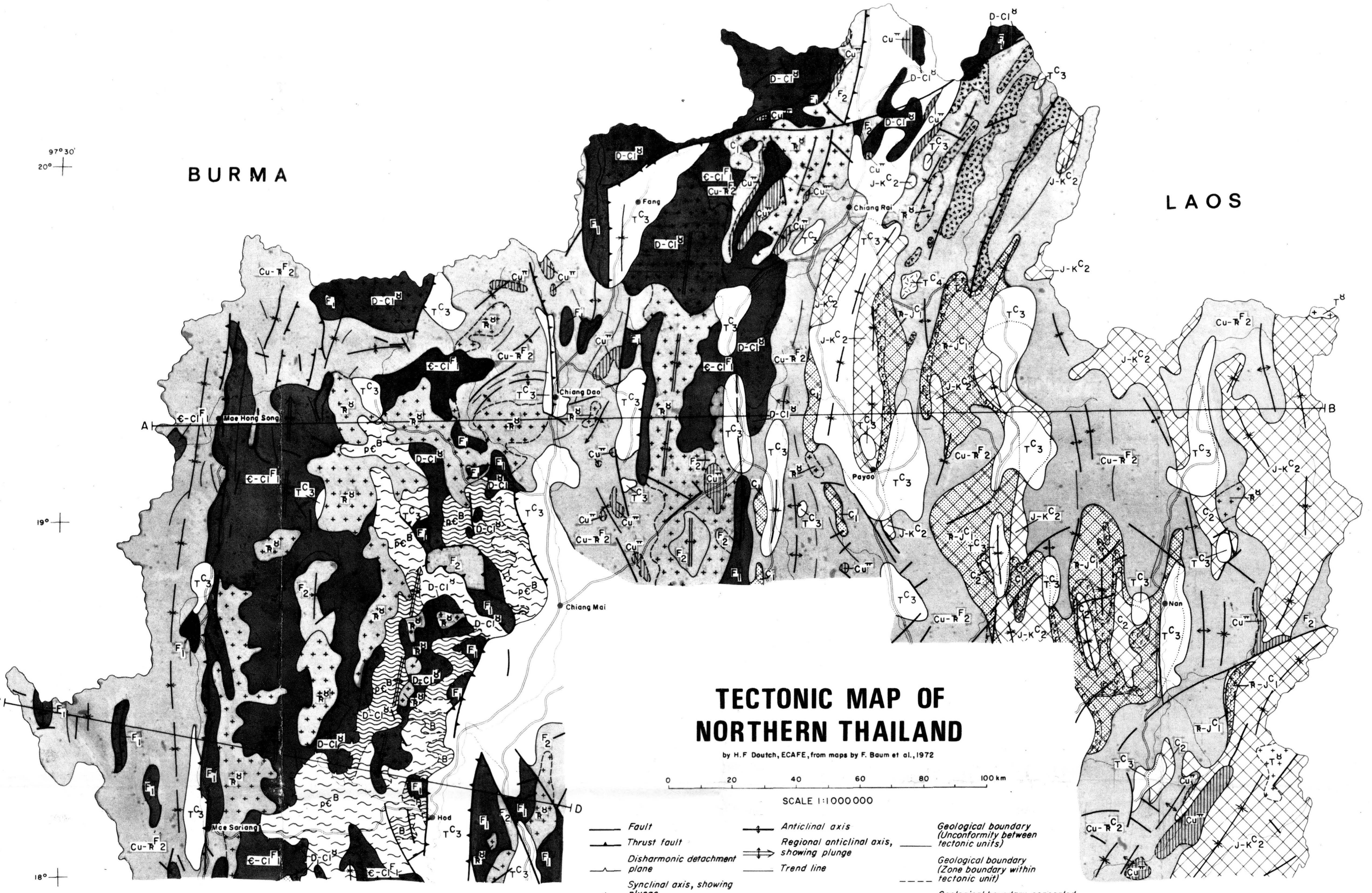
Stöcklin (1968)		Yanshin (ed.-1966)
Structural zones:		(Regions of Alpine folding)
Kopet Dagh		
Alborz Mountains	---------------	Elburz Mega-anticlinorium
Sanadaj-Sirjan	-------?-------	Isfahan-Saydabad Downwarp
Zagros Thrust Zone } Zagros Folded Belt }	-------	Zagros Anticlinorium
East Iran-Makran		

JAPAN

Isomi (1968)	Yanshin (ed.-1966)
Terrane consolidated by the Variscan Orogeny.	}
Terrane of intense Pacific Orogeny	'Unnamed'
Belts of Himalayan Orogeny	Morphotectonic
Belt of Mesozoic and Himalayan Orogenies (Ryukyu)	zones.
Kuril Arc	}
Belt of Alpine Orogeny	}

TECTONIC MAP OF NORTHERN THAILAND

by H.F Doutch, ECAFE, from maps by F. Baum et al., 1972

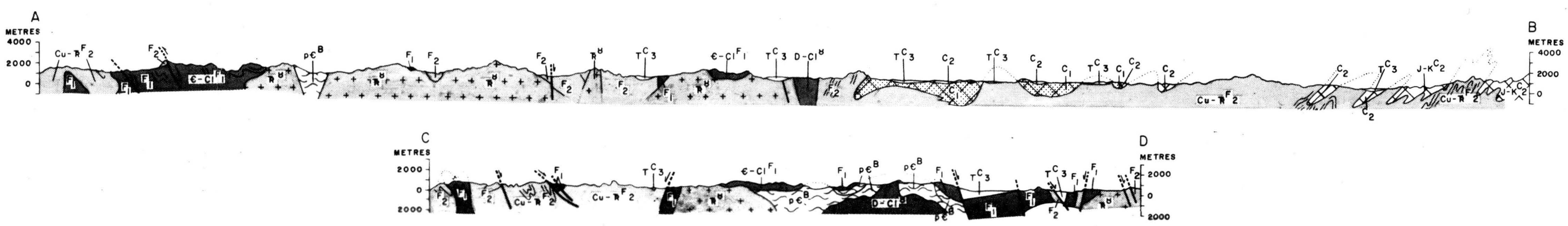


Fault	Anticlinal axis
Thrust fault	Regional anticlinal axis, showing plunge
Disharmonic detachment plane	Trend line
Synclinal axis, showing plunge	

Geological boundary (Unconformity between tectonic units)

Geological boundary (Zone boundary within tectonic unit)

Geological boundary, concealed



TECTONIC UNITS

Tertiary basalt

FAULT-CONTROLLED BASIN

T^{C}_{3} — Late (?) Tertiary fluviatile and lacustrine sandstone, siltstone, and clay

POST-CRETACEOUS FOLDING OF COVER

Probably affected whole area, producing post-Hercynide north-south fold trends. Synchronous with granite ?

COVER ON FOLD BELTS - originally continuous with cover on 'Indosinian Massif'

$J-K^{C}_{2}$ — Jurassic and Cretaceous continental red sandstone and shale, with minor marine limestone.

$R-J^{C}_{1}$ — Norian and Jurassic conglomerate and andesitic to rhyolitic flows and pyroclastics. Latest Triassic/Jurassic folding

FOLD BELTS - 'Yunnan - Malaya' Geosyncline

'Indosinides' $Cu-R^{F}_{2}$ — Late Carboniferous to Triassic marine sandstone and shale, commonly red, and limestone. Local, mainly andesitic, pyroclastics. Norian folding.

'Hercynides' $Є-Cl^{F}_{1}$ — Cambrian to early Carboniferous marine sandstone, shale and limestone. Early Carboniferous orogenesis - fold trends north/south

METAMORPHICS

$pЄ^{B}$ — Anatexis of Precambrian Basement resulting from 'Hercynide' orogeny

BASEMENT

$pЄ^{B}$ — Precambrian folding and high grade metamorphism of clastics and limestone. Paragneiss towards base. Structures strike north/south, east/west.

GRANITOIDS

Early (?) Tertiary granite, granodiorite Syn-tectonic with post-Cretaceous folding ?

Pre-late Triassic, post-Permian granite, granodiorite. Syn-orogenic in 'Indosinides'

D-Cl — Pre-late Carboniferous, post-Silurian granite. Syn-orogenic in 'Hercynides'

OPHIOLITES

Cu — Beginning of late Carboniferous. Gabbro, pyroxenite, diabase, andesite, amphibolite. Early geosynclinal in 'Indosinides'

VOLCANICS

Andesite, rhyolite

Andesite

Basalt

0/5/57