INTER-ARC BASINS AS OCEANIC CRUST TRAPPED BETWEEN TWO SUBSEQUENT SUBDUCTIONS

Jean-François Parrot(1), François Dugas(1) and Hubert Whitechurch(2)

(1) Géologues O.R.S.T.O.M., *Laboratoire de Géologie, S.S.C. O.R.S.T.O.M., 70, 74, route d'Aulnay F. 93140 Bondy*
(2) *Laboratoire de Minéralogie et Pétrographie, 1, rue Blessig F. 67084 Strasbourg Cedex*

Abstract

Evidence (magnetic lineations, sedimentary cover) of large spreading in inter-arc basins separating the remmant volcanic arc from the active one is not actually sure. This paper explores the possibility of relating the remnant arc to an old subduction process and the active arc to a new subduction developped in front of the previous one. In that case, the floor of inter-arc basins would be formed by an old oceanic crust trapped between two Benioff zones. The geometry of two cases is described: a system with two subsequent parallel subduction planes and a system where the most recent subduction plane dips more steeply than the old one. The different parameters used to define the geometry of the systems are: dips of the Benioff zones; thickness of the lithosphere; depth of the volcanic source; distance between the two arcs; distance from each arc to the active tench. The position of an eventual remnant trench can be determined from the geometric relationships between those parameters and searched on the bathymetric profiles. The models were tested on five inter-arc basins from the western Pacific: Ogasawara (Bonin) — Iojima — Nishishichito; Mariana; Kermadec — Havre — Colville; Tonga — Lau; Vanuatu (New Hebrides). Apart the Vanuatu system, the calculated geometrical features of those basins are in good accordance with those deduced from the geophysical data. The model with two subsequent parallel subductions without spreading could account for the Ogasawara — Iojima — Nishishichito and the Kermadec — Havre — Colville systems. The geometry of the Mariana and Tonga-Lau is compatible with either model in which the two subduction planes have different dip or a model with two parallel subductions implying a spreading of 50 and 150 km maximum respectively. In the Vanuatu system, the differences existing between the calculated geometric parameters and those deduced from geophysic suggest a compression in the basin itself.

Résumé

Bassins inter-arcs : un plancher océanique situé entre deux subductions consécutives

Les arguments permettant d'étayer l'hypothèse d'une large expansion dans les bassins inter-arcs séparant l'arc remanant de l'arc actif (linéations magnétiques, couverture sédimentaire) sont peu sûrs. Cet article envisage la possibilité de lier l'arc remanant à une subduction fossile, l'arc actif se développant au droit d'une nouvelle subduction fonctionnant au front de l'ancienne. Dans ce cas, le plancher océanique des bassins inter-arcs serait constitué essentiellement d'une vieille lithosphère océanique comprise entre deux plans de Benioff. La géométrie de deux situations possibles est décrite : un système dans lequel les deux zones de subduction sont parallèles et un second dans lequel elles ont des pendages différents. Les paramètres utilisés pour définir la géométrie de ces systèmes sont : le pendage des plans de Benioff ; l'épaisseur de la lithosphère, la profondeur de la source volcanique, la distance entre les deux arcs, la distance de chaque arc à la fosse active. La position d'une éventuelle fosse rémanante peut être calculée et donc recherchée sur les profils bathymétriques. Les deux modèles ont été testés sur cinq bassins inter-arcs du Pacifique occidental : Ogasawara (Bonin) — Iojima — Nishishichito ; Marianes ; Kermadec — Havre — Colville ; Tonga — Lau ; Vanuatu (Nouvelles Hébrides). Mis à part celles de ce dernier système, les caractéristiques géométriques calculées s'accordent bien avec celles déduites de la géophysique de ces bassins. Un modèle avec deux zones de subduction parallèles, sans faire intervenir d'expansion notable peut s'appliquer aux bassins Ogasawara — Iojima — Nishishichito et Kermadec — Havre — Colville. La géométrie des bassins des Marianes et Tonga — Lau est compatible *avec un modèle dans lequel les deux zones de subduction ont un pendage différent ou avec un modèle dans lequel les deux zones de subduction sont parallèles impliquant, alors, une expansion de respectivement 50 et 150 km au maximum. Les différences existantes entre les données géométriques calculées dans le bassin de Vanuatu et ses caractéristiques déduites de la géophysique suggèrent qu'il ait subi une compression.*

Резюме

МЕЖДУГОВЫЕ БАССЕЙНЫ : ОКЕАНСКОЕ ДНО, РАСПОЛОЖЕННОЕ МЕЖДУ ДВУМЯ ПОСЛЕДОВАТЕЛЬНЫМИ СУБДУКЦИЯМИ

Аргументы, подтверждающие предположение большого расширения в междуговых бассейнах, отделяющих остаточную дугу от активной дуги (магнитные линейности, осадочный чехол) являются маловероятными. Настоящая статъя исследует возможность ассоциации остаточной дуги с ископаемой субдукцией, пока активная дуга развивается перпендикулярно к новой субдукции, действующей на передней стороне прежней. В таком случае, океанское дно междуговых бассейнов преимущественно состоялось бы из древней океанской литосферы, включенной между двумя поверхностями разломов БенЬоффа. Описанна геометрия двух возможных положений : систем1, в которой обе зоны субдукции — параллельны, и вторая система, в которой они имеют различные падения. Чтобы определить геометрию этих систем употребляют следующие параметры : падение плоскостей разломов Беньоффа ; толщина литосферы, глубина вулканического источника, расстояние между двумя дугами, расстояние между каждой дугой и активным желобом. Положение возможного остаточного желоба можно вычислять и следовательно исследовать по батиметрическим профилям. Оба модели испытали в пяти междуговых бассейнах Западного Тихого Океана : Огазавара (Бонин) — Иожима — Нишишичито ; Марианские острова ; Кермадек — Гавр — Колвиль ; Тонга — Лау ; Ваунату (Новые Гебриды). Кроме тех последней системы, вычисленные геометрические особенности хорошо согласуются с особенностями, выведенными из геофизики этих бассейнов. Модель, включающая две параллельной зоны субдукции не вовлекая значительного расширения, применимая к бассейнам Огазавара — Иожима — Нишишичито и Кермадек — Гавр — Колвиль. Геометрия бассейнов Марианoвых островов согласуется с моделЬю в которой обе зоны субдукции имеют различные падения, или, с моделью в которой обе зоны субдукции — параллельны, что подразумевает максимальное расширение, соответственно равное 50 и 150 км. По существующим разницам между геометрическими данными, рассчитанными в бассейне Вануату и его геофизическими особенностями, можно считать, что он был подвергнут некоторому сжатию.

INTRODUCTION

Active inter-arc basins related to trench-arc systems are mainly located in the Western Pacific. They correspond to a particular type of back-arc basin where the basin is situated between two volcanic arcs: an arc presently active and directly in relation with the subduction; a back-arc corresponding to an earlier volcanic range. The basin itself is composed of oceanic crust with a thin sediment cover. Such examples have been described in Ogasawara (Bonin)-Iojima-Nishishichito, Mariana, Vanuatu (New Hebrides), Tonga-Lau and Kermadec-Havre-Colville arc systems.

Although the fundamental process occuring under the trench-arc systems is the subduction of an oceanic plate, not all those systems have back-arc basin. By definition, the continental arcs have no back-arc basins and the presence of those basins requires firstly the formation of intra-oceanic subductions but, as emphasized by UYEDA and KANAMORI (1979), the subduction of an oceanic plate is not a sufficient condition for the formation of back-arc basins, although it may be a necessary one.

Different possibilities have been proposed to explain the formation of marginal or back-arc basins:

(1) opening related to a "leaky" transform fault (WILSON, 1965; CURRAY *et al.*, 1979);

(2) opening related to the subduction of a ridge (UYEDA and MIYASHIRO, 1974) ;

(3) subsidence caused by oceanisation of continental crust (BELOUSSOV and RUDITCH, 1961 ; KATZ, 1976, 1978).

None seems sufficient to give a full explanation for the formation of the inter-arc basins as they have been defined above.

In fact, two other possibilities appear as more appropriate :

(a) Back-arc spreading caused by or related to the intra-oceanic subduction (BARKER, 1970; KARIG, 1970; 1971a and b; 1974; MATSUDA and UYEDA, 1971; UYEDA and KANAMORI, 1979).

(b) Entrapment of preexisting oceanic crust by the formation of an island arc (UYEDA and BEN AVRAHAM, 1972; COOPER *et al.*, 1976).

A back-arc basin would be actively opening if it presents one of the two following characteristics: (1) magnetic lineations with zero age; (2) thin sediment cover of very young age.

A part from the difficulty in dating with precision magnetic lineations which are more or less irregular in the back-arc basins (LAWVER and HAWKINS, 1978), we have to notice that they are not often parallel to the direction of the trench, as we could theoritically expect it for spreading axis and magnetic lineations of the inter-arc basin, if its formation would have been directly related to an extension in the upper plate consecutive to the subduction; unless up-rising of effusive manifestations leading to spreading have used a pre-existing network of fractures "en échelon" which could have been formed on the upper plate by a possible compression occuring at the begining of the subduction. And, where the identification of the magnetic lineations is sure, i.e. in the Aleutian basin, they present a Mesozoïc age (COOPER *et al.*, 1976).

Drillings in the back-arc sediment cover did not show that the base of the sedimentary sequence is getting younger when the holes were closer to the supposed spreading axis (HUSSONG and UYEDA, 1978). Moreover, the tholeiites of the basaltic basement are quite similar to the MORB, but this does not mean, as PINEAU *et al.* (1976) claimed on the basis of oxygen isotope data, that, in back-arc basins, we are faced with a process similar to that observed in mid oceanic ridges. This observation proves only that back-arc basins are made up of oceanic material. In this case, it could certainly be part of a pre-existing ocean.

All those reasons led us to take into account a process mainly based on the entrapment of an oceanic crust.

In the case of inter-arc basins which are the main concern of this paper, entrapment would occur in a way described further. In any case, entrapment does not exclude up-rising of igneous and effusive intrusions forming high ridges and mountains scattered throughout the inter-arc basin (KATZ, 1976) ; these magmatic manifestations would be related to fracturing of the upper plate (LAWVER and HAWKINS, 1978), eventually leading to local spreading.

DESCRIPTION OF THE MODEL

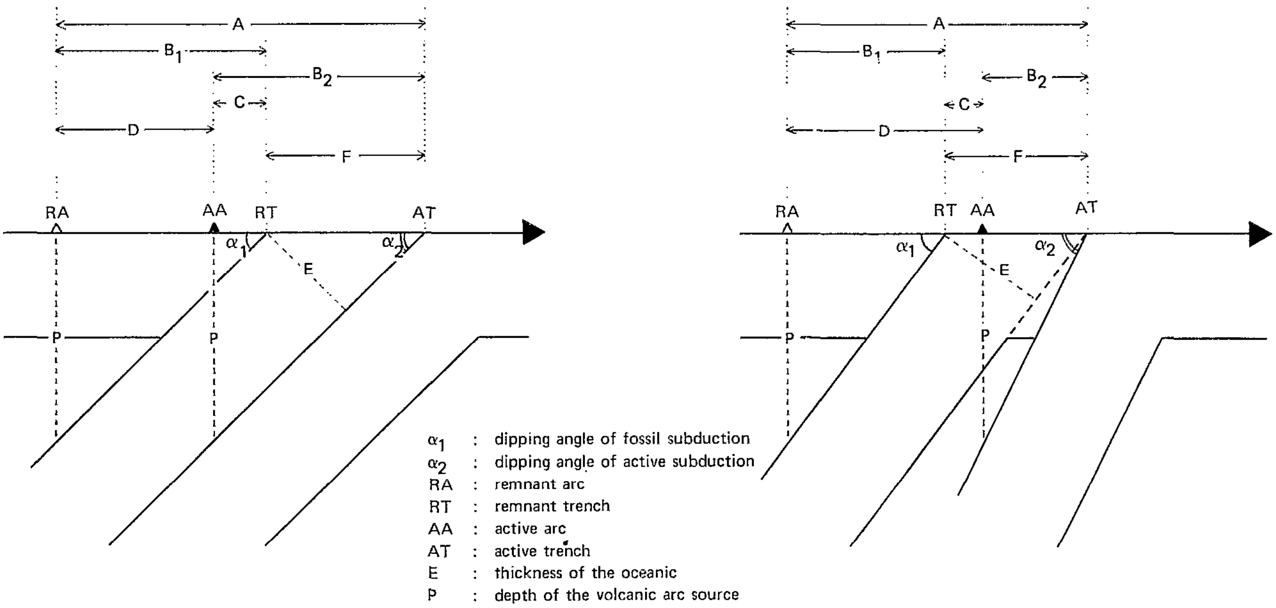
In a scheme based on field relationships in the Eastern Mediterranean region, PARROT and WHITECHURCH (1978) have interpreted the ophiolite-related metamorphic rocks located at the base of each ophiolitic massif, as the result of the transformation of oceanic volcanic and sedimentary series as they enter in an intra-oceanic subduction zone. The geometry and the disposition of the three different east-west ophiolitic belts of this region, led them to suppose the existence of different ocean-directed subductions affecting the Tethyan oceanic crust before its tectonic emplacement southwards on to the arabo-african platform. The trenches related to those three subductions would have been parallel and the downgoing slab of the most recent subduction would sink beneath the slab of the previous one, involving a jump of the subduction zone.

In order to explain the formation of low temperature deformed peridotitic tectonites, NICOLAS and LE PICHON (1980) have proposed a shearing of the oceanic crust, 15 km or so under the bulge of the downgoing plate (DUBOIS *et al.*, 1977). And this shearing would be responsible for the development of a new subduction zone 120 km or so in front of the previous one.

We postulate that the present inter-arc basins of the Western Pacific were essentially induced by such a phenomenon.

Model with two parallel subduction zones

We admit that the second or active subduction occurs in front of the previous one, and that the new downgoing slab slips down beneath the former slab with the same dip. It is necessary to see the implication of such an hypothesis on the geographic distribution of the remnant arc (RA), the active arc (AA) and the eventual trace of the remnant trench (RT) since we correlate the remnant arc to a prior subduction. The distance of those three different units from the position of the active trench (AT) depends on the thickness of the oceanic lithosphere, the depth of volcanic arc source which, according to different authors, varies between 100 to 150 km, even 200 km, and the dip of the two slabs. On the theoretical section of Figure 1A, the dip is the angle between the horizontal and the line joining the trench to the volcanic source without taking account of the real shape of the Benioff-Wadati zone which is in fact convex (KARIG *et al.*, 1976). On the same figure, the distance A corresponds to the distance between the remnant arc (RA) and the active trench (AT). B is the distance between arc and trench. C is the distance between the active arc (AA) and the remnant trench (RT); all the



α_1 : dipping angle of fossil subduction
α_2 : dipping angle of active subduction
RA : remnant arc
RT : remnant trench
AA : active arc
AT : active trench
E : thickness of the oceanic
P : depth of the volcanic arc source

$\alpha_1 = \alpha_2 = \alpha$
$A = RA \rightarrow AT = P/\tan\alpha + E/\sin\alpha$
$B_1 = B_2$
$B_1 = RA \rightarrow RT = P/\tan\alpha$
$B_2 = AA \rightarrow AT = P/\tan\alpha$
$C = AA \rightarrow RT = P/\tan\alpha - E/\sin\alpha$
$D = F$
$D = RA \rightarrow AA = E/\sin\alpha$
$F = RT \rightarrow AT = E/\sin\alpha$

$\alpha_1 < \alpha_2$
$A = RA \rightarrow AT = P/\tan\alpha_1 + E/\sin\alpha_1$
$B_1 \neq B_2$
$B_1 = RA \rightarrow RT = P/\tan\alpha_1$
$B_2 = AA \rightarrow AT = P/\tan\alpha_2$
$C = AA \rightarrow RT = P/\tan\alpha_2 - E/\sin\alpha_1$
$D \neq F$
$D = RA \rightarrow AA = P/\tan\alpha_1 + E/\sin\alpha_1 - P/\tan\alpha_2$
$F = RT \rightarrow AT = E/\sin\alpha_1$

FIG. 1. — Theoretical cross-sections of inter-arc basin systems induced by a frontal jump of the subduction zone
Coupes théoriques de bassins inter-arcs résultant d'un saut frontal de la zone de subduction

distances being defined as vectors, we have to notice that C is positive when the remnant trench (RT) is situated in front of the active arc (AA), and that C is negative when the trace of the remnant trench (RT) is located in the inter-arc basin, behind the active arc (AA); finally, D corresponds to the distance between the two volcanic arc (RA and AA), that is to say the width of the inter-arc basin; in the single graphical construction of Figure 1A, D is equal to F, the distance between the two trenches. As shown on the figure, the values of the six different vectors depend on three parameters: the dip angle (α); the thickness of the lithosphere (E); the depth of the volcanic source (P).

On Figure 2, are shown the distances A, B, C and D as a function of the dip for an oceanic lithosphere 80 km thick and a volcanic source located 125 km beneath the sea-line. We notice that C is either negative, positive or equal to zero corresponding in this case to the position of the active arc (AA) and the remnant trench (RT) in the same point.

The positive or negative value of C distribute the inter-arc basins into two systems: in the first one (positive C), the trace of the remnant trench is situated in front of the active arc, whereas in the second one (negative C), this trace is located in the inter-arc basin itself. In the first system, a break on the frontal slope of the active arc has to be expected on the bathymetric profiles, and in this case, as retained by SEELY (1979), the prism is not essentially composed of sediments but oceanic crust slices may be present. On the other hand, we have to notice that the systems with a back-arc remnant trench (negative C) are more abundant when the oceanic lithosphere is thick and/or the dip important.

Otherwise, the evolution of the distance D (inter-arc basin width) ranges within relatively narrow limits: from 64 km for a 70° dipping of a slab 60 km

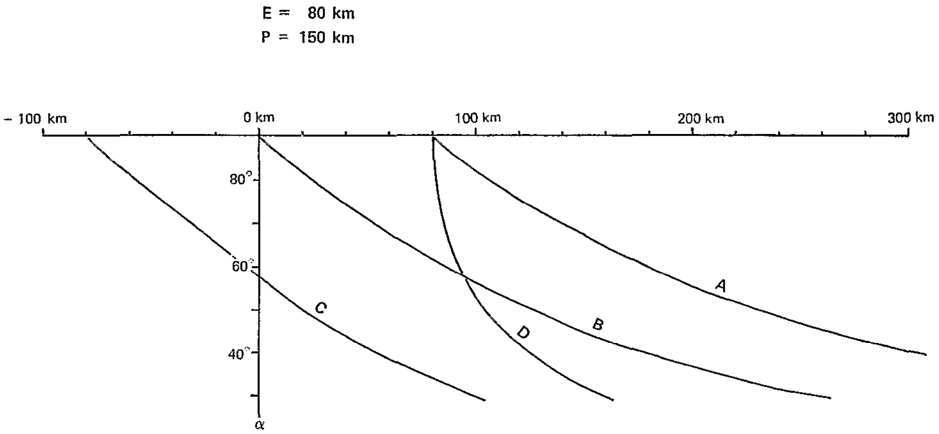


FIG. 2. — Evolution of the distances A, B, C and D as a function of the dip for an oceanic lithosphere 80 km thick and a volcanic source located 150 km beneath the sea level

Évolution des distances A, B, C et D en fonction du pendage pour une lithosphère océanique de 80 km d'épaisseur et une source volcanique située de 150 km en dessous du niveau de la mer

thick, to 160 km for an oceanic lithosphere with a thickness of 80 km and which dips with an angle of 30°, even to 200 km for a 30° dipping of a slab 100 km thick. When the two slabs present the same angle of dipping (hypotenuse of the diagram of the Figure 3), the depth of the volcanic arc source has no influence on the width of the inter-arc basin, since D is only related to the thickness of the lithosphere ($D=E/\sin \alpha$).

Model with two different dipping subduction zones

Larger inter-arc basins can be created by the way proposed in the general model which in fact includes the previous one. As shown in the Figure 1B, the new downgoing slab does not necessarily present the same angle of dipping as the previous one, and the lithospheric lower plate can sink at a steeper angle than the slab under which it slips.

Thus, the evolution of the different vectors is not defined as above by 3 parameters, but by 4:

thickness of the oceanic lithosphere (E);
depth of the volcanic source (P);
dip of the first subduction (α_1);
dip of the second subduction (α_2);

The diagram of Figure 3 shows the evolution of the vectors B, and D which are easily measurable, and C which is more difficult to perceive. This diagram have been constructed for a lithosphere 100 km thick and a volcanic source depth located at 150 km beneath the sea level. The evolution of the dip angles have been limited from 30° to 70°.

When α_2 is different from α_1, the length of the inter-arc basin (D) depends not only on the lithosphere tickness, but also on P values. Thus, D is likely to grow with an increase in P and the difference between α_1 and α_2.

The conjunction of the values B_2 and D permits to define the place occupied by a system on a diagram of this type, and this, all the better as in many cases the known shape of the Benioff-Wadati zone allows to calculate the angle α_2.

APPLICATION AND DISCUSSION

The hypothesis on which the model is based can be tested when the distances obtained by the geometric construction, are in good accordance with the distances measured in each actual inter-arc system. The validity of the model will be checked better if the number of known parameters is high; because in this case, the constraints induced by the parameters do not allow any deviation between measured, assumed and calculated distances. On the contrary, an important deviation would imply the existence of factors other than a single geometric construction provided by the model based on the oceanic entrapment hypothesis.

In fact, the values B_2 (distance from the active arc to the active trench), D (inter-arc basin width) and A (total width of the system) can be easily measured either on a bathymetric map or a bathymetric cross section; on the other hand, we can estimate from seismic data the parameters α_2 and P (we can also obtain this last value by the relation $P=B_2 \times \tan \alpha_2$); it is more problematical to apprehend, in a first approach, the position of the remnant trench (RT) on the bathymetric profiles, because

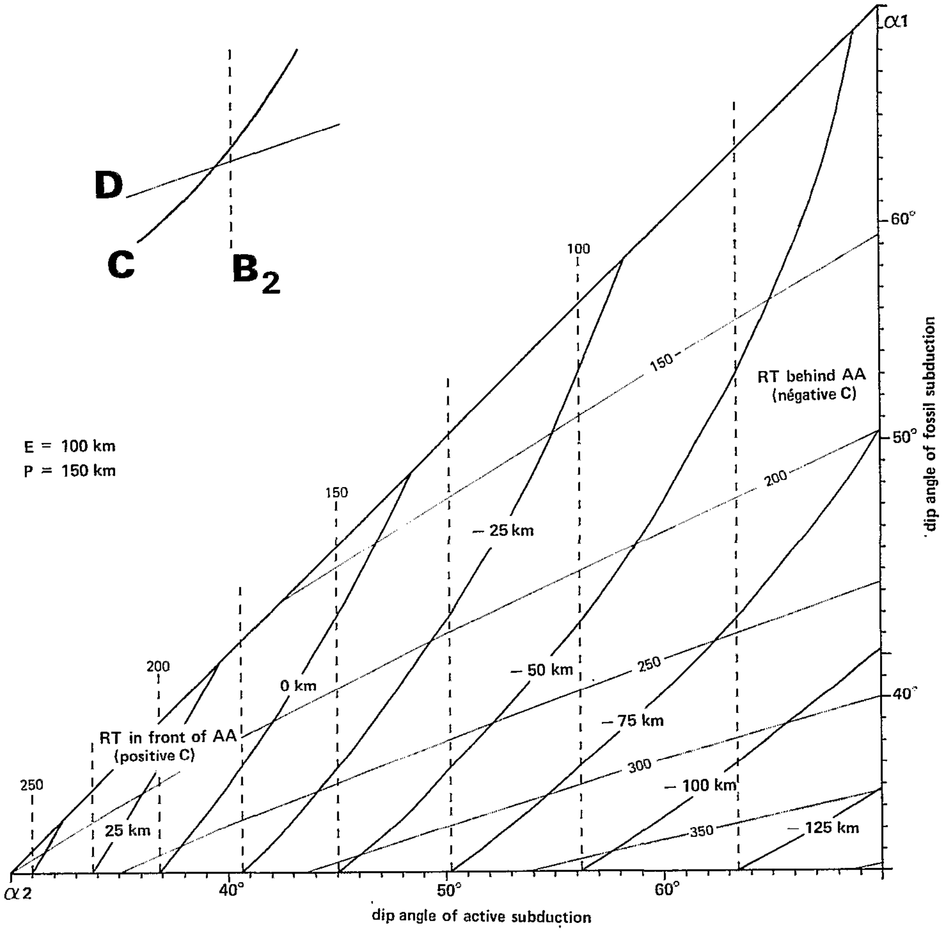


FIG. 3. — Evolution of B_2, C, and D in the diagram α_1 versus α_2 (for an oceanic lithosphere 100 km thick and a volcanic source located 150 km beneath the sea level)

Évolution de B_2, C et D dans le diagramme α_1 en fonction de α_2 (pour une lithosphère océanique de 100 km d'épaisseur et une source volcanique située à 150 km en dessous du niveau de la mer)

in several cases they present different depressions which could correspond to the unknown position of the ancient trench. And the vector C corresponding to the distance comprised between the active arc (AA) and the remnant trench (RT), is one of the most important element to discriminate the system. Furthermore, although varying within narrow limits the thickness of the lithosphere (E) is difficult to evaluate.

For all those reasons, the method consists in calculating different possibilities to obtain the same measured values (B_2, D and A) of an inter-arc system with more or less well-defined parameters (P and α_2), and with a regular variation of the parameter E and the correlative one α_1. From different E values, the same measured vectors can be obtained, except C and correlatively B_1 which register different answers; i.e. with P=120 km and α_2=45°, we obtain the same values for A (299), B_2 (120) and D (179), either with E=100 km and α_1=40°, or E=80 km and α_1=36,25°; but, in the first case, C is equal to —36 km (B_1=143 km), and in the second one, C is equal to —15 km (B_1=164 km). Thus, when in a first appearance on the bathymetric profile, the definition of C remains problematical, one of the calculated C values may correspond to one of the most important depression zones of this profile, which in this case could be considered as a possible witness for the remnant trench.

We will explore now whether or not the geometric relationships between all the components of the five actual inter-arc basin systems of the West and Southwest Pacific (Fig. 4) are in accordance with those defined by means of the model.

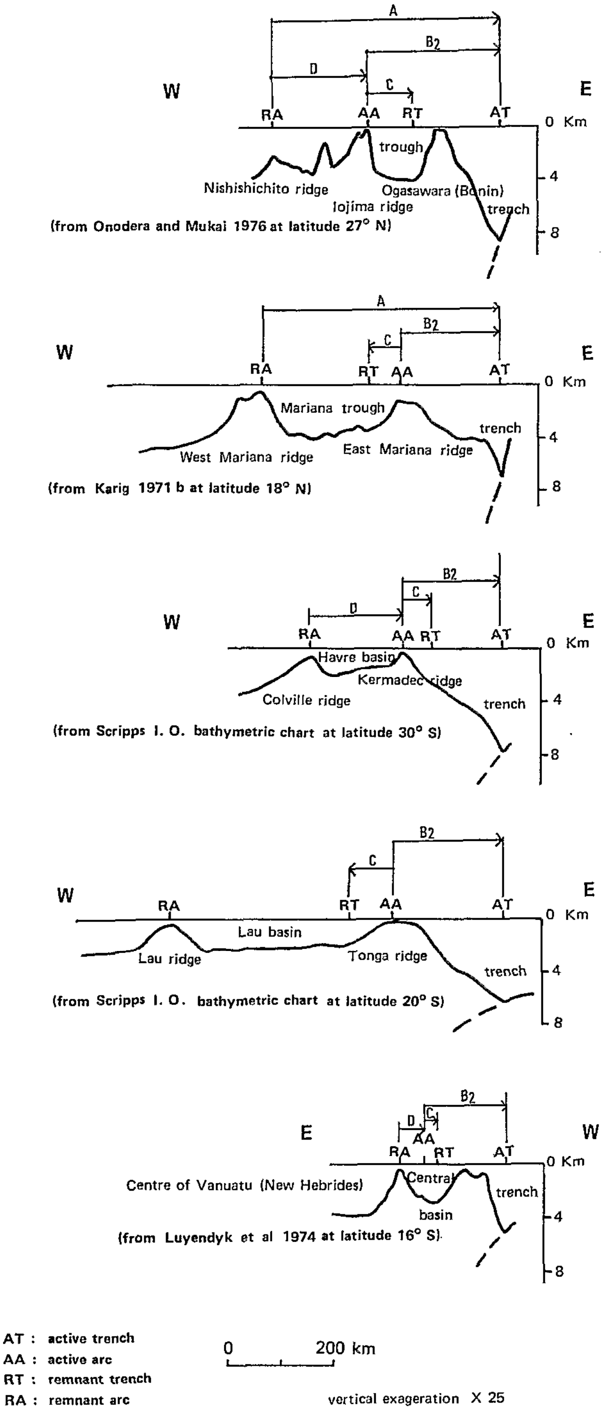


FIG. 4. — Bathymetric cross-sections of the West and Southwest Pacific inter-arc basin systems

Profils bathymétriques de bassins inter-arcs du Pacifique occidental et sud-occidental

TABLE I

Evolution of the inter-arc basin width (D) depending on the values of E, P, α_1 and α_2 (distances in km)

Évolution de la largeur (D) de bassins inter-arcs en fonction des valeurs de E, P, a_1 et a_2 (distances en km)

E	P	D		
		$\alpha_1 = 70°$ $\alpha_2 = 70°$	$\alpha_1 = 30°$ $\alpha_2 = 30°$	$\alpha_1 = 30°$ $\alpha_2 = 70°$
60	100 125 150	64	120	257 291 325
80	100 125 150	85	160	296 331 365
100	100 125 150	106	200	336 371 405

Furthermore, we have to notice that, according to the model, one can expect, between the end of the last effusive manifestations in remnant arc and the begining of the volcanic activity in active arc, the time corresponding to the gap generally observed between the two volcanic arcs surrounding marginal basins. This time depends on dip and subduction rate of the second downgoing slab, i.e. for 35° and 5 cm/y rate, the slab will reach only after 4.5 My, 130 km that is to say the mean depth of volcanic source.

Ogasawara (Bonin)-Iojima-Nishishichito system

At about latitude 27° N (ONODERA and MURAI, *in* INOUE, 1976), the distance B_2 dividing the active arc from the active trench is 250 km long, D which fixes the boundaries of the inter-arc basin from the remnant arc to the active arc is 165 km or so, and the total width of the system (A) is then 415 km. In the Ogasawara-Iojima-Nishishichito system, the inter-arc basin (D), as defined in the model, is not made up of a real basin and comprises a succession of highs and depressions; it has nothing to do with the Ogasawara trough located there in front of the active volcanic arc and which could correspond, in a first approximation to the eventual trace of the remnant trench. In a first approach, we assume that this trough corresponds to the trace of the remnant trench, the distance C (AA-RT) could

TABLE II

Comparison between measured and assumed values and calculated values of the studied inter-arc basin systems

(1) INOUÉ (1976) at 27° N
(2) KARIG and MOORE (1975) at 28° N
(3) KATSUMATA and SYKES (1969)
(4) LUYENDIK (1970)
(5) KARIG (1971 b), HUSSONG *et al.* (1978) at 18° N
(6) BRACEY and OGDEN (1972)
(7) KARIG (1970) at 32° S
(8) SYKES (1966) at 32° S
(9) DUBOIS *et al.* (1977)
(10) BARAZANGI and ISACKS (1971), MITRONOVAS and ISACKS (1971)
(11) SYKES (1966) at 20 and 22° S
(12) HAWKINS (1974) at 21° S
(13) OLIVER *et al.* (1973)
(14) KARIG (1971 a)
(15) DUGAS *et al.* (1977)
(16) DUBOIS *et al.* (1978)
(17) PASCAL *et al.* (1978)

Comparaison entre les valeurs mesurées, estimées et calculées des bassins inter-arcs étudiés

	OGASAWARA (Bonin) IOJIMA – NISHISHICHITO			MARIANA			KERMADEC – HAVRE COLVILLE			TONGA-LAU			VANUATU (New-Hebrides)		
	measured	assumed	calculat	measured	assumed	calculat	measured	assumed	calculat	measured	assumed	calculat	measured	assumed	calculat
D (Km)	165(1)		165	285(5)		285	140(7)		140	355 to 365(10)(11)(12)		365	30(15)		76
B_2 (Km)	250(1)(2)		250	215(5)		215	180(7)(8)		180	207(11) 210(10) 220(12)		210	150(15)		150
α_2	38°(3)		38	28 to 35(6)		31	43(8)		43	31 to 32(13) 38(10) 33 to 36(11)		32	52(16) 52 to 55(17)		52
P (Km)	200(3)(4)		195	100 to 120(6) 130 to 140(3)		130	165 to 175(8)		168	100(14) 100 to 120(13) 125(10) 138 to 146(11)		131	180(16) 190(17)		190
E (Km)		100	100		120	120	90,6 to 109,7(9)		96	90,6 to 109,7(9)		110	62 to 67(9)		60
α_1			37° 48'			27° 55'			43			23° 36'			52
C (Km)		+80	+ 87		– 40	– 41		+ 50	+ 40		– 65	– 65		+ 40	+ 72
B_1 (Km)		245	251		245	243		190	179		300	300		70	150

range from +60 to 80 km, with a more important probability for +80. If this measure is correct, the correlated distance B_1 linking the remnant arc to the remnant trench is around 245 km. According to the seismic profiles given by KATSUMATA and SYKES (1969) and LUYENDYK (1970), the depth of the actual volcanic source (P) is about 200 km and the dip angle α_2 of the active subduction is around 38°. This angle combined with the B_2 value of 250 km places the volcanic source 195 km under the sea level. With the same P value for the ancient and actual subduction, and an angle α_2 of 38°, the calculated vectors (cf. Table II) show that the agreement is quite perfect when the lithosphere (E) is 100 km thick, implying so an α_1 equal to α_2. Thus, when drawing on the bathymetric map the position of the remnant trench induced by the C value, we can notice the good accordance between this position and the axis of the Ogasawara trough, and starting from this point, the good accordance between all the measured, assumed and calculated values.

Mariana system

The different vector values given in the Table II have been defined from a bathymetric cross-section located at 18° N (KARIG, 1971b). In a first approximation, the trace of the remnant trench is supposed to be situated in front of the axial high of the Mariana trench; by means of the calculation, this choice does not appear so problematical in relation to the constraints resulting from the values A, B_2, D, the mean values of the parameters P and α_2, and the assumed value of E.

On the other hand, for KATSUMATA and SYKES (1969) the depth of the volcanic source under the sea level would range from 130 to 140 km; for BRACEY and OGDEN (1972) the P value would not be so important; they give an estimation of 100 to 120 km. We can also obtain, from the seismic data of BRACEY and OGDEN (1972), an estimation of 28° to 35° for α_2. All the constraints induced by those values show that the interpretation of the depression located in front of the axial high of the Mariana trench as a witness of the remnant trench is not problematical as it appears in a first approach. Thus, for a B_2 value of 215 km and a mean value of 31° for α_2, P is equal to 130 km. A good accordance between measured assumed and calculated values is obtained with a lithosphere 120 km thick and an α_1 equal to 28°.

So, as for the precedent inter-arc system, a single geometric construction according to the proposed model, is able to provide a system comparable to the Mariana system, without taking into account a spreading phenomenon.

In fact in this case, a light spreading of about 50 km would be possible if one can assume that α_1 was equal to α_2.

Kermadec-Havre-Colville system

At latitudes 30° and 32° S (KARIG, 1970), B_2 is equal to 180 km, D to 140 km and A to 320 km. Otherwise, DUBOIS *et al.* (1977) proposed a lithospheric calculated thickness ranging from 90,6 to 109,7 km, and, in the seismic profiles given by SYKES (1966) at latitude 32° S, the dip angle α_2 is 43°. Thus, with a distance B_2 equal to 180 km and an α_2 equal to 43°, the volcanic source would be situated 168 km under the sea level.

In Table II, a good accordance between measured and calculated values is obtained for a lithosphere 96 km thick with $\alpha_1=\alpha_2=43°$. Furthermore, the geometric construction imposes a limit of 95 km for the thickness of the lithosphere; this limit emphasizes the validity of the result proposed by DUBOIS *et al.* (1977). On the other hand, the geometric construction implies a positive C, that is to say a position of the remnant trench in front of the active arc as observed in the Bonin system. And so, there is a possibility to interpretate the depression located in the frontal slope of the volcanic active arc (DUPONT, 1979), as a witness of the remnant trench.

We can conclude, as in the Ogasawara (Bonin) system, that the disposition of the Kermadec system does not require any spreading.

Tonga-Lau system

The values A, B_2 and D were measured at latitude 22° S (BRYAN *et al.*, 1972; HAWKINS, 1974); furthermore, considering in a first approach the valley located in the Lau Basin in front of the axial ridge as a possible witness of the remnant trench trace, B_1 and C have been estimated. On the other hand, the oceanic lithosphere would be 80 km thick (BARAZANGI and ISACKS, 1971), or even range from 90,6 to 109,7 km (DUBOIS *et al.*, 1977). The evaluation of P is rather difficult since it varies between 100 and 140 km according to different authors (Table II); α_2 would range from 31° to 36°. In fact, for a mean value of 32° for α_2, the volcanic source would be situated at 131 km under the sea level, if we retain 210 km for B_2.

The measured values A, B_2 and D are obtained by the geometric calculation for E equal to 100 km and E equal to 110 km; in the first case, α_1 is equal to 22.6° and C to —50 km; in the second one, α_1 is equal to 23.6° and C to —64.7 km, that is to say very close to its estimated value.

As for all the precedent examples, there is a possibility to find again the measured and assumed values by means of the geometric construction; but, as for the Mariana system and even more in this case, the important difference between α_1 and α_2 (about 8°), would allow an eventual spreading of about 150 km if one can assume that α_1 was equal to α_2.

Vanuatu (New Hebrides) system

At latitude 15° S (DUGAS *et al.*, 1977; 1983), A is equal to 180 km, B_2 to 150 km, and D to 30 km. Furthermore, the thickness of the lithosphere ranges from 62 to 67 km (DUBOIS *et al.*, 1977); the α_2 value would be 52° and P range from 180 to 190 km (DUBOIS *et al.*, 1978; PASCAL *et al.*, 1978). Induced by α_2 and B_2 values, the depth of the volcanic source is in fact equal to 192 km.

As shown in Table II, the measured distances are not in accordance with the calculated values; the smaller calculated A an D values are much more important than the equivalent measured values; and it is impossible to obtain smaller values since α_1 cannot be superior to α_2 (52°).

In this case, the interest of such a geometric construction is to demonstrate the existence of a compression in the Vanuatu (New Hebrides) system at this latitude. This compression is posterior to the jump of the subduction, perhaps in relation with the arrival of the d'Entrecasteaux rise in the subduction zone.

CONCLUSIONS

(1) The geometric construction induced by the model based on oceanic entrapment by the frontal jump of the subduction zone, takes into account all the West and South-West Pacific inter-arc basin systems. Furthermore, the geometric construction allows to fix probable boundaries to parameters such as the thickness of the lithosphere (E) and the

depth of the volcanic source (P). On the other hand, the correspondance between measured and calculated values implies parameters which are always in good accordance with the geophysical datas.

(2) The calculation leads us to define the eventual position of the trace of the remnant trench among the depressions observed in the bathymetric profiles.

(3) The present inter-arc systems can be divided into three groups:

(a) In Ogasawara (Bonin)-Iojima-Nishishichito and Kermadec-Havre-Colville systems, the geometric construction shows that the formation of those systems does not need any spreading.

(b) In Mariana and Tonga-Lau systems, the model implies an angular difference between the two downgoing slabs. If one can assume for these exemples that the previous dipping was equal to the present one, one can expect an eventual spreading posterior to entrapment: 50 km maximum of new oceanic crust in Mariana and 150 km maximum in Tonga-Lau would be created. In fact, we have searched principally to demonstrate that the spreading is not a sine qua non condition for the formation of inter-arc basin. Furthermore, we have to notice that the existence of an angular difference between the dipping of the two slabs is correlated with an important thickness of the lithosphere. Thus, a progressive sinking in the mantle of the second slab is not suprising, and leg 60 in Mariana basin shows obviously a frontal displacement of the volcanic products with time.

(c) The Vanuatu (New Hebrides) system indicates that the minimal calculated values are higher than the measured values, implying in this case the existence of a compression.

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