Geological Interpretation of the Cuban K-Ar Database

M. Iturralde-Vinent, G. Millán, L. Korpas, E. Nagy, J. Pajón

Abstract

The Cuban K-Ar database comprises age determinations ranging from Late Proterozoic to Miocene. However, if dates with errors >10 % are eliminated, reliable ages (n=189) concentrate within the Late Proterozoic, Jurassic, Cretaceous, Paleocene and Eocene. Determinations of Paleozoic, and Oligocene to Recent ages are questionable and probably incorrect. The interpretation of the K-Ar database is focused in two directions: one according to geological units, and the other according to the peaks found in a frequency histograms.

The interpretation of the database according to geological units shows that all results are from samples of the Cuban foldbelt that encompasses Late Eocene and older continental and oceanic units.

Of the continental units (Bahamas platform, Pinos and Escambray terranes), the oldest rocks belong to the Bahamas basement (945±20 - 910±25 Ma) which reflect a Grenville event. Jurassic K-Ar ages (150±5 - 139±6 Ma) are also found within magmatic rocks of the Bahamas platform. Some of these K-Ar ages are a rejuvenated dating of small granite bodies of U-Pb 172,4 Ma, but also from basalts at the passive continental margin. The Pinos and Escambray terranes, built up by metamorphic rocks, yield K-Ar ages from Late Cretaceous to Eocene (85±4 - 43±5 Ma).

These ages reflect the final metamorphism and uplift of both massifs.

In the oceanic units (Northern ophiolites, Cretaceous volcanic arc and Paleogene volcanic arc), the oldest rocks are found in the Northern ophiolites (160±24 Ma). Also the oldest oceanic metamorphic rocks are high-P metaophiolites (128±5 - 126,3±8,3 Ma). The wide range of ages in the ophiolites (160±24 - 52±6 Ma) is the result of the combined action of magmatic and tectono-metamorphic events.

Rocks of the Cretaceous volcanic arc display generally younger ages than the ophiolites (100,1±3,8 - 49,5±3,5 Ma), suggesting that each geological unit have evolved independently. K-Ar ages from the Cretaceous volcanic arc reflect both magmatic and tectonic events. The last important magmatic event in the arc is the intrusion of the main plutonic body during Campanian, with a K-Ar cooling age estimated as 79 Ma. Maastrichtian to Eocene K-Ar ages of arc rocks are probably due to tectonic events. K-Ar ages for the Paleogene volcanic arc are all from the plutonic bodies. The K-Ar age of the intrusion cooling is estimated as 47 Ma, with younger ages (41,6±5 - 39±4 Ma) probably representing later tectonic deformations.

The overall evaluation of the K-Ar ages with errors ≤10 % shows that most of the ages are clustered around a maximun of 65-75 Ma, a period that represents the extinction of the Cretaceous volcanic arc and an important

change in the tectonic evolution of the western Caribbean. A minimum of 9 peaks are evident in the K-Ar frequency histogram for ages <150 Ma. These peaks commonly represent important magmatic, metamorphic and/or tectonic events in the history of the geological units accreted in the Cuban foldbelt. Most of these events can be recognized also by geologic means, and are the followings:

135-145 Ma (Berriasian-Valanginian), 115-125 Ma (Aptian-Barremian), 105-110 Ma (Albian), 90-95 Ma (Cenomanian), 80-85 (Early Campanian), 65-75 Ma (Maastrichtian), 60-65 Ma (Thanetian-Danian), 50- 55 Ma (Lutetian-Ypresian), 42- 45 Ma (Priabonian-Lutetian).

Resumen

La base de datos cubana de dataciones K-Ar comprende edades desde el Neoproterozoico hasta el Miocene. Sin embargo, si las dataciones con error > 10 % son eliminadas, las edades confiables (n=189) se concentran en el Neoproterozoico, Jurásico, Cretácico, Paleoceno y Eoceno. Las determinaciones de edades del Paleozoico y Mioceno a Reciente son cuestionables y probablemente incorrectas. La interpretación de la base de datos se encamina en dos direcciones: una de acuerdo a las unidades geológicas del cinturón plegado de Cuba, y la otra de acuerdo a los picos del histograma de frecuencias para todas las dataciones con error ≤ 10 %.

La interpretación de la base de datos de acuerdo a las unidades geológicas de naturaleza continental y oceánica, muestra que todas ellas pertenecen al cinturón plegado de edad pre Eoceno Superior tardío.

En las unidades continentales (plataforma de Bahamas, Terrenos Pinos, Guaniguanico y Escambray), las rocas más antiguas pertenecen probablemente al basamento de las Bahamas (945±20 - 910±25 Ma), las que reflejan un evento Grenville. Edades Jurásicas (150±5 - 139±6 Ma) se encuentran entre las rocas magmáticas del talud de las Bahamas, edades que correlacionan con eventos magmáticos propios del margen continental. Los Terrenos Pinos y Escambray, constituidos por rocas metamórficas, presentan edades desde Cretácico Superior hasta Eoceno (85±4 - 43±5 Ma). Estas edades corresponden con el último evento de metamorfismo y levantamiento de esos macizos.

En las unidades oceánicas (Ofiolitas septentrionales, arcos volcánicos del Cretácico y Paleógeno), las rocas más antíguas se encuentran entre las ofiolitas septentrionales (160±24 Ma). También las más antíguas metamorfitas oceánicas (128±5 - 126,3±8,3 Ma) son ofiolitas metamorfizadas en condiciones de alta presión. El amplio rango de edades en las ofiolitas (160±24 - 52±6 Ma) es el resultado de la acción combinada de eventos magmáticos y tectono-metamórficos. Las rocas del arco volcánico Cretácico (100,1±3,8 - 49,5±3,5 Ma) presentan generalmente edades K-Ar más jóvenes que las ofiolitas, un hecho que sugiere que ambas unidades geológicas evolucionaron independientemente. Las edades K-Ar del arco cretácico reflejan tanto eventos tectónicos como magmáticos. El último evento importante en el arco fue la intrusión del cuerpo principal de rocas plutónicas en el Campaniano, cuya edad de enfriamiento se estima en 79 Ma.

Las dataciones con edades Maastrichtiano a Eoceno en rocas del arco y las ofiolitas, corresponden a eventos tectónicos que rejuvenecen la edad K-Ar. Las dataciones en el arco del Paleógeno son todas de rocas plutónicas. Las edades K-Ar permiten estimar la edad de enfriamiento de la intrusión como 47 Ma. Las dataciones más jóvenes en estas rocas (41,6±5 - 39±4 Ma) representan el rejuvenecimiento por eventos tectónicos.

La evaluación global de todas las dataciones K-Ar con error ≤ 10 % muestran que la mayoría de las edades se agrupan alrededor de un pico en los 65-75 Ma. Este dato coincide con la extinsión del arco volcánico cretácico y un cambio del regimen tectónico en el Caribe noroccidental. Un mínimo de 9 picos térmicos se evidencian en el histograma de frecuencias. Estos picos a menudo representan importantes eventos tectónicos, magmáticos y/o metamórficos en la historia geológica de las unidades amalgamadas en el cinturón plegado cubano. Se correlacionan con eventos geológicos en las edades siguientes:

135-145 Ma (Berriasiano-Valanginiano), 115-125 Ma (Aptiano-Barremiano), 105-110 Ma (Albiano), 90-95 Ma (Cenomaniano), 80-85 (Campaniano temprano), 65-75 Ma (Maastrichtiano), 60-65 Ma (Thanetiano-Daniano), 50- 55 Ma (Lutetiano-Ypresiano), 42- 45 Ma (Priaboniano-Lutetiano).

INTRODUCTION

During the last 30 years, over 300 isotopic ages have been determined from Cuban rocks. They include 267 by the K-Ar method and the rest by means of other techniques (Thermo-Pb, U-Pb, ^{40}Ar-^{39}Ar, etc.). These data have been scattered in the Cuban and international geological literature, but they are now compiled into a database (Iturralde-Vinent et al. 1992). This database had two previously unpublished versions one by C. M. Judoley and the other by E. Linares.

In this paper K-Ar ages are summarized in several tables according to the geological units present in the Cuban foldbelt (Fig. 1), along with a brief discussion about the geologic and tectonic interpretations of these data. This interpretation is focused in two ways, first by geological units and second, according to a histogram of the K-Ar ages < 150 Ma.

Assessment of the database

Although the ages by the K-Ar method have been processed in 12 different laboratories during 3 decades, the results show a good consistency since, with few exceptions, rocks sampled from the same localities and dated by different laboratories yield fairly similar ages, with the exception of determinations done on different minerals. The K-Ar ages of the rocks rarely correspond to the protolithic ages. Usually the age is a minimum for the rocks. This is clearly evidentiated in figure 2, where the age range of the rocks identified by stratigraphic and paleontologic methods is compared with K-Ar ages identified from rocks of the same geological units. Basically, K-Ar dating is useful in identifying the main regional tectonic-magmatic events that have affected the rocks and generally this is the latest, as has been demonstrated by different authors (Meyerhoff et al. 1969, Somin and Millán 1981, Iturralde-Vinent et al. 1989, Iturralde-Vinent et al. 1992).

The K-Ar ages obtained in Cuban rocks include values which vary from the Neoproterozoic (945±20, 910±25 Ma)[2] to the Miocene (16±31 Ma), although this latter is most likely wrong. However, in general, the great majority of ages occur between 42 and 128 Ma and are distributed around a maximum at 75-65 Ma. Cuban rocks that have been dated by paleontologic methods are typically Jurassic, Cretaceous, Paleogene, Neogene and Quaternary in age. However, only those older than late Upper Eocene present important deformations with regional or contact metamorphism, magmatism and/or hydrothemal alteration. Late Upper Eocene and younger rocks are sedimentary with very little deformation and without metamorphism. Consequently, they have not been the subject of sampling for the study of their isotopic age.

In the database there are a few determinations that record very ancient ages. Some of these correspond to rocks of the crystalline basement of the Bahamas whose Late Proterozoic age (945±20, 910±25 Ma) is not in any doubt. However, some ages determined to be Late Paleozoic (450±50, 255±7, 247±20) were obtained in high-pressure mafic metamorphic rocks, and are not reliable as will be explained later.

An aspect that relates to the quality of the K-Ar datings is the precision of the age determination which we give in millions of years and percentage. The errors in percentage have the following distribution:

Total of determinations	267
With errors ≤5%	106
With errors >5 and ≤10%	83
With errors >10 and ≤15%	32
With errors >15 and ≤20%	11
With errors >20%	35

These data indicate that most of the

2 Every age is refered to the Decade of North America time scale.

determinations are acceptable for this type of dating. There are 189 ages (70%) with error ≤10%. These results cover all the rock complexes belonging to the foldbelt and are a good basis for an interpretation of Cuban geology and tectonics.

GEOLOGICAL INTERPRETATION

In the geological constitution of Cuba two main structural levels are recognized. These are the foldbelt and the neoautochthon (Figure 1). The grouping of the K-Ar ages is based on the principal geological structures that are present in the Cuban foldbelt (Figure 1) according to the tectonic framework proposed by Iturralde-Vinent (1992). This classification is an important base in order to evaluate the K-Ar ages and comprises the following elements (Figs. 1 and 2):

Continental units

- Bahamas plattform
- Socorro Complex (Bahamas basement)
- Escambray Terrane
- Pinos Terrane
- Guaniguanico Terrane

Oceanic units

- Northern ophiolites (melange)
- Allochthonous ophiolite melange in Guaniguanico
- Cretaceous island arc
- Guira de Jauco Amphibolites
- Mabujina Amphibolites
- Paleogene island arc

In order to appropriately characterize these units, rocks were further subdivided according to genesis, composition and degree of metamophism into mafics, sialics, high-P metam., high-T metam., plutonics, extrusives, hornfels, etc.

The database includes K-Ar ages of samples taken in almost all of the magmatic and metamorphic complexes that are present in the foldbelt, with the exception of the volcanics and metamorphics of the Paleogene volcanic arc. The greatest number of samples for K-Ar datings are concentrated in the plutonic rocks of the Cretaceous volcanic arc (n=74), in contrast to the rest of the complexes, which have between 4 and 55 determinations.

The rocks and structures of the neoauthochthon were formed after the consolidation of the foldbelt; that is, since Late Upper Eocene. During this period, vertical oscillatory movements dominated, which gave rise to the formation of a block structure (grabens and horsts). Deposits of this stage are only slightly deformed with the exception of some narrow strips associated with the Pinar, La Trocha and Oriente sinistral faults. For this reason there are no K-Ar dates that refer to thermal events that occurred during this stage.

The available K-Ar isotopic ages are briefly discussed below according to the geological units previously defined.

Bahamas Platform

The Bahamas Platform outcrops along part of the northern half of the Cuban territory (Figure 1). Within its limits, rocks of two structural levels outcrop: the sialic basement and the Meso-Cenozoic sequences. The carbonate platform contains Jurassic to Late Eocene clastics, evaporites and limestones. Southward, the section changes into isochronous continental slope and basinal deposits composed of limestones, shales, fine-grained clastics and cherts (Khudoley 1967, Meyerhoff and Hatten 1968, 1974, Pardo 1975).

A possible metamorphic equivalent of the paleoslope sections of the Bahamas crops out in eastern Cuba and is named the Asunción massive (Figure 1; Somin and Millán 1981).

Most of the K-Ar ages obtained from samples of the Bahamas continental margin come from the sialic basement and correspond to the Socorro complex (Table 1) that outcrops in central Cuba (Figure 1). As well, there are other dates that most probably belong to this basement. These are found as blocks in the northern ophiolite melange north of Holguin, and in the San Adrián diapir (Table 2).

In the Socorro Complex, two ages are recognized. The oldest corresponds to a Grenville event (Somin and Millán 1981) and was corroborated by means of the ^{40}Ar-^{39}Ar

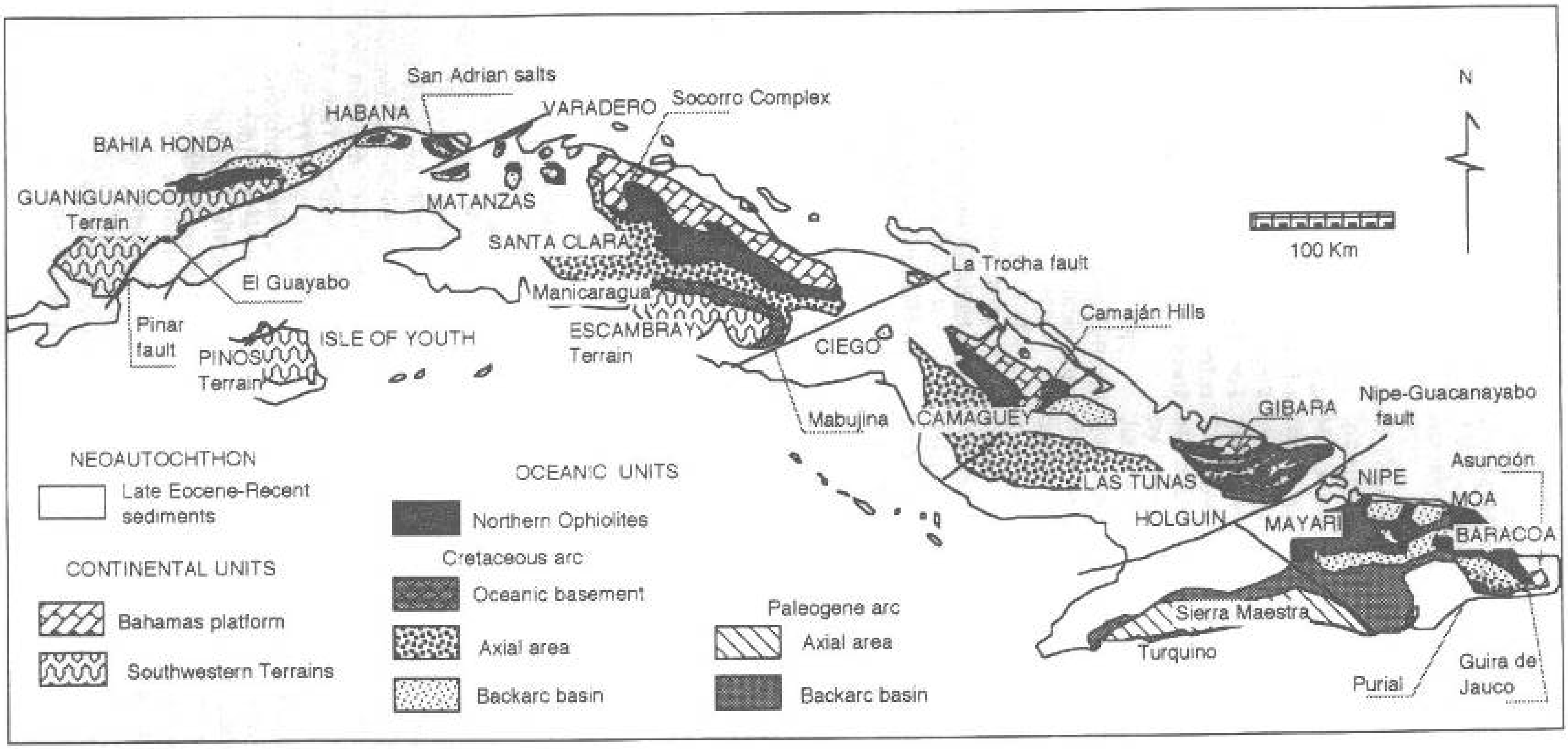

Figure 1. Generalized geological map of the Cuban foldbelt (with patterns) showing some pertinent localities. The neoautochthon is the patternless area. No K-Ar samples have been taken from these rocks.

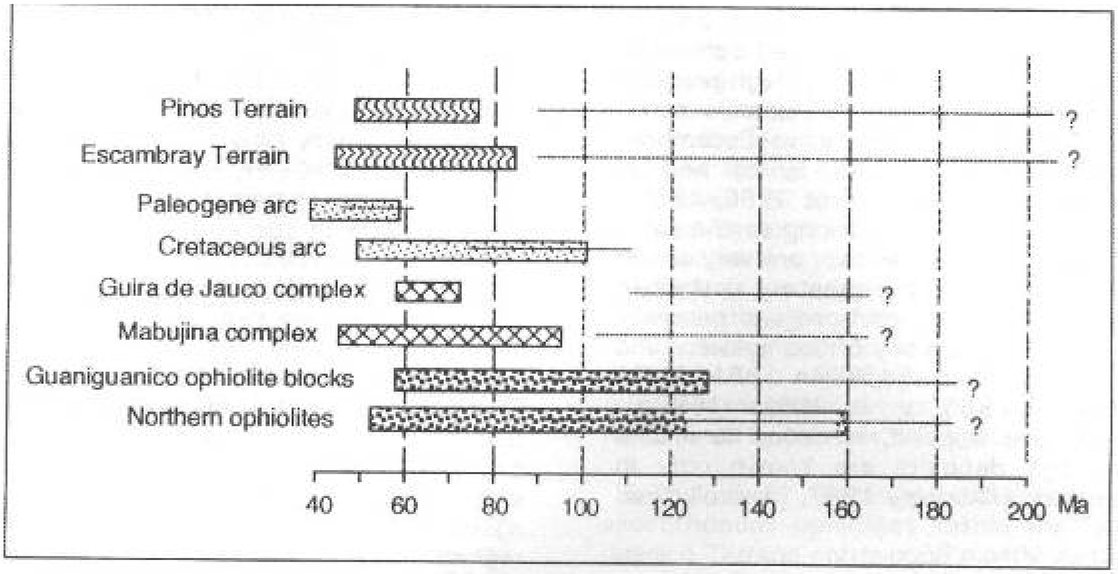

Figure 2. Comparison of the age range of the protoliths determined by a complex of geological methods (thin line) and the K-Ar ages of the rocks (thick pattern).

method as 903,5±7,1 Ma. The younger age belongs to small granite bodies that cut the Proterozoic rocks. Their U-Pb age is 172,4 Ma (Renne et al. 1989) and K-Ar ages 139-150 Ma (Somin and Millán 1981). The latter probably correspond to a younger thermic event. These rocks are covered by unmetamorphosed arkosic sands and deformed Tithonian marine sedimentary deposits (Pardo 1975)

Only one sample that undoubtedly belongs to the Meso-Cenozoic sequences of the Bahamas paleoslope was the subject of K-Ar dating. It corresponds to a basalt flow within Tithonian sedimentary rocks dated by microfossils. It outcrops in Sierra de Camaján (Figure 1) and yields a K-Ar age of 146±6 Ma, which dates the magmatic event (Iturralde-Vinent et al. 1989).

From the blocks of sialic metamorphic rocks (gneiss, crystalline schists and marbles) found within the northern ophiolite melange and in the salt diapir at San Adrián, Matanzas, Middle Jurassic and Cretaceous K-Ar ages were obtained. These rocks presumably are fragments detached from the Bahamas slope deposits (Table 2, Somin and Millán 1981, Kubovics et al. 1989). These ages probably reflect thermal events related to the tectonic deformations of the rocks in the foldbelt. Such deformations are also identified by geological observations (Pardo 1975, Pszczolkowski and Flores 1986, Iturralde-Vinent 1989).

Cuban Southwestern Terranes

In central and western Cuba, three tectonostratigraphic terranes can be distinguished. They are known as: Guaniguanico, Pinos and Escambray (Figure 1, Iturralde-Vinent, 1994). The geology of these terranes is very complicated since they contain different types of lithostratigraphic sections that are tectonically mixed, deformed and metamorphosed (Pszczolkowski 1978, Pardo 1975, Millán 1981, 1990, Somin and Millán 1981). In all three terranes, the Jurassic and Cretaceous sedimentary deposits of continental passive margin type dominate, with interbedded layers of basalts dated as Lower-Middle Jurassic, Oxfordian, Tithonian and Lower Cretaceous (Iturralde-Vinent 1988). In the Guaniguanico and Escambray terranes, Mesozoic ophiolites are found (serpentinites, gabbroids, diabases, basalts) in thrust planes and as blocks and slivers in the olisthostromes and chaotic rocks (Iturralde-Vinent 1989).

In Escambray, there are ophiolites partially metamorphosed under high-pressure conditions.(Millán 1992a). Cretaceous meta-volcanic rocks are present in Escambray (Millán and Somin 1985 a, b) and in Guaniguanico (Iturralde-Vinent 1988, 1989). These terranes probably belong to the same paleogeographic realm as they are very similar to one another with the greatest similarities between the Jurassic sections and generally between the stratigraphy of Guaniguanico and Escambray (Somin and Millán 1981, Millán and Somin 1985 a, b, Millán 1992a). However, late Upper Cretaceous to Middle Eocene age deposits are known only in Guaniguanico (Khudoley 1967, Pszczolkowski 1978).

The K-Ar ages from the Pinos and Escambray terranes are from metamorphic rocks that are essentially autochthonous in these terranes and that reflect a common history (Tables 3 and 4). In the Pinos Terrane, the paleontologic date indicate a Mesozoic age for the metaterrigenous-carbonate protolith sequences and there is no criterion at all that might suggest a younger age (Somin and Millán 1981). Small dikes (K-Ar 60-65 Ma) related to mineral deposits intrude the metamorphic rocks. They are youngest, but the age can not be geologically restricted. Thus, the Campanian (78±4 Ma) to Eocene (49,3±3,8 Ma) K-Ar ages in the metamorphic rocks of Pinos Terrane probably reflect thermal events linked to the last stage of regional metamorphism and later cooling and uplift (Table 3).

The Escambray Terrane contains pre-Maastrichtian metaterrigenous and carbonate rocks whose ages have been established by means of fossils and rough lithostratigraphic correlations with unmetamorphosed equivalent sections in Guaniguanico (Millán 1992b). The oldest K-Ar ages of 210±13 and 255±7 Ma (Hatten et al. 1988) obtained from the glaucophane in glaucophanic schists, and from the hornblende in an eclogitic rock, respectively, have been interpreted by some authors as proof of the existence of Paleozoic rocks in the Escambray (Khudoley and Meyerhoff 1971, Mossakovsky et al. 1986). However, this opinion is questionable since an excess of radiogenic argon trapped in the amphibole might have produced anomalous older dates. Younger ages have been obtained in these very rocks. In the eclogite, the hornblende was dated as 85 Ma by the ^{40}Ar-^{39}Ar method (Hatten et al. 1989). Paragonite yielded 75±4 Ma (K-Ar) and metamorphic zircon yielded 102±2 Ma (U-Pb). On the other hand, the phengite of the glaucophanic schist yielded an age of 68±1 Ma (Somin & Millán 1981, Hatten et al. 1989).

The rest of the K-Ar ages of Escambray (Table 4) correspond very well with the age values from the Pinos Terrane (Table 3). These ages are from metamorphic rocks of different types, degrees of metamorphism and compositions, as well as from late synmetamorphic veins. The set of oldest K-Ar ages probably correspond with the last stage of regional metamorphism of this terrane, while the youngest ages may be dating the cooling and uplift of these rocks since Maastrichtian.

The comparison of the range of reliable K-Ar ages obtained in the metamorphic rocks of Pinos and Escambray, whose values are practically coincidental, suggests that these terranes suffered synchronous tectono-metamorphic events during latest Cretaceous to early Tertiary, as described by Millán (1992a). The perfect correlation on their median values may coincide with the approximate age of the last major metamorphic event (Latest Cretaceous 66±4 Ma).

K-Ar ages from the Guaniguanico Terrane are only a few (Table 5) as these rocks have been dated paleontologically from Lower-Middle Jurassic till Lower-Middle Eocene (Pszczolkowski 1978). Gneisses from El Guayabo conglomerate, located south of the Guaniguanico Terrane east of Pinar del Río city (Fig. 1), probable represent basement rocks, but they display very young K-Ar ages (71±3 - 55±6 Ma). Only two samples were collected from the Lower(?) to Late Jurassic (early Oxfordian) slightly metamorphosed San Cayetano Formation, one within the age span of the formation (196±8 Ma), but the other younger (119±10 Ma). Nevertheless, probably both represent minimum ages.

Northern Ophiolites

These rocks outcrop as lenticular bodies in the northern half of Cuba, between Cajálbana to the west and Baracoa to the East (Figure 1). In fact, they are tabular sheets, strongly dismembered, and up to 6 kilometers thick where the rocks are deformed as part of a tectonic melange. This melange includes autochthonous and exotic metamorphic rocks. The ophiolites have been described by several authors (Khudoley and Meyerhoff 1971, Pardo 1975, Iturralde-Vinent 1989, Andó et al. 1989).

K-Ar ages from the Northern ophiolites are mostly from blocks of metaophiolites (high-P and low-P) along with a few magmatic rocks (Table 6).

The table of K-Ar ages of the Northern ophiolites shows that they present a wide range of ages between 160±24 (Jurassic) and 52±6 Ma (Eocene) which are grouped into small clusters. This reflects the long succession of tectono-magmatic events that have affected these rocks since their formation. The ages from high-P rocks in the Northern ophiolites are in good agreement with those obtained in similar rocks of the Guaniguanico Terrane (Table 7). Therefore, it is likely that ophiolites found in thrust planes within the Guaniguanico Terrane and the Northern ophiolites are the same body of ophiolites, as has been interpreted by some authors (Somin and Millán 1981, Pszczolkowski 1978, Iturralde-Vinent 1989).

An isolated sample of eclogite from the Northern ophiolites was dated as early Paleozoic from piroxene (450±50 Ma), but it is in doubt as from the same sample there are ages of 126±10 in moscovite and 105±10 in hornblende (Table 6). Another Paleozoic age of an eclogite from Guaniguanico (hornblende 247±20 Ma) is again problematic, since two other ages from the same sample are youngest (110 from moscovite and 96 from whole rock; Table 7).

The high-pressure metaophiolite inclusions are normally characterized by a range of ages between 128±10 and 67±7 Ma. Within this range, the dates can be arranged by stages in the following way: Neocomian (6), Aptian (5), Albian (11), Cenomanian-Campanian (8), Maastrichtian-Paleocene (2). These K-Ar ages suggest that part of the ophiolites suffered from high-pressure metamorphic events in the Lower Cretaceous (as a minimum), which makes them the oldest Mesozoic metamorphic rocks found in Cuba within the oceanic units. The K-Ar ages obtained in the low-pressure metaophiolites are between 82 and 68 Ma which may reflect thermal events linked to the oceanic magmatism, or later retrograde effects obliterating the original age of the protolith. Likewise, the ages of the non-metamorphosed rocks determined in whole rock samples (160±24 to 57,8±5,4 Ma) probably represent magmatic events, perhaps somewhat rejuvenated by tectonic deformations.

The K-Ar datings obtained from allochthonous ophiolites within the Guaniguanico Terrane correspond mostly to high-P metamorphic rocks included as blocks in chaotic deposits or in serpentinitic thrust sheets (Table 7; Pszczolkowski 1978, Somin and Millán 1981).

Cretaceous volcanic arc

Rocks of the Cretaceous volcanic arc are found on the island of Cuba and in the northwestern part of the Isle of Youth (Figure 1, Pardo 1975, Eguipko et al. 1984, Kozák et al. 1988, etc). These rocks may be divided into various complexes, such as:

- oceanic basement
- volcano-sedimentary section
- plutonics
- metamorphics

These complexes are all present in Cuba, but have lateral variations (Figure 1; axial zone, backarc basin). Although there are different opinions about the nature of the basement of the Cretaceous volcanic arc, there is little doubt that the arc originated on oceanic crust. Part of this crust is probably represented within the Mabujina and Guira de Jauco amphibolites (Figure 1, Millán and Somin 1985 a, b, Haydoutov et al. 1989, Iturralde-Vinent 1989). As both amphibolitic complexes are composed of metamorphic rocks mainly of magmatic origin, there is no

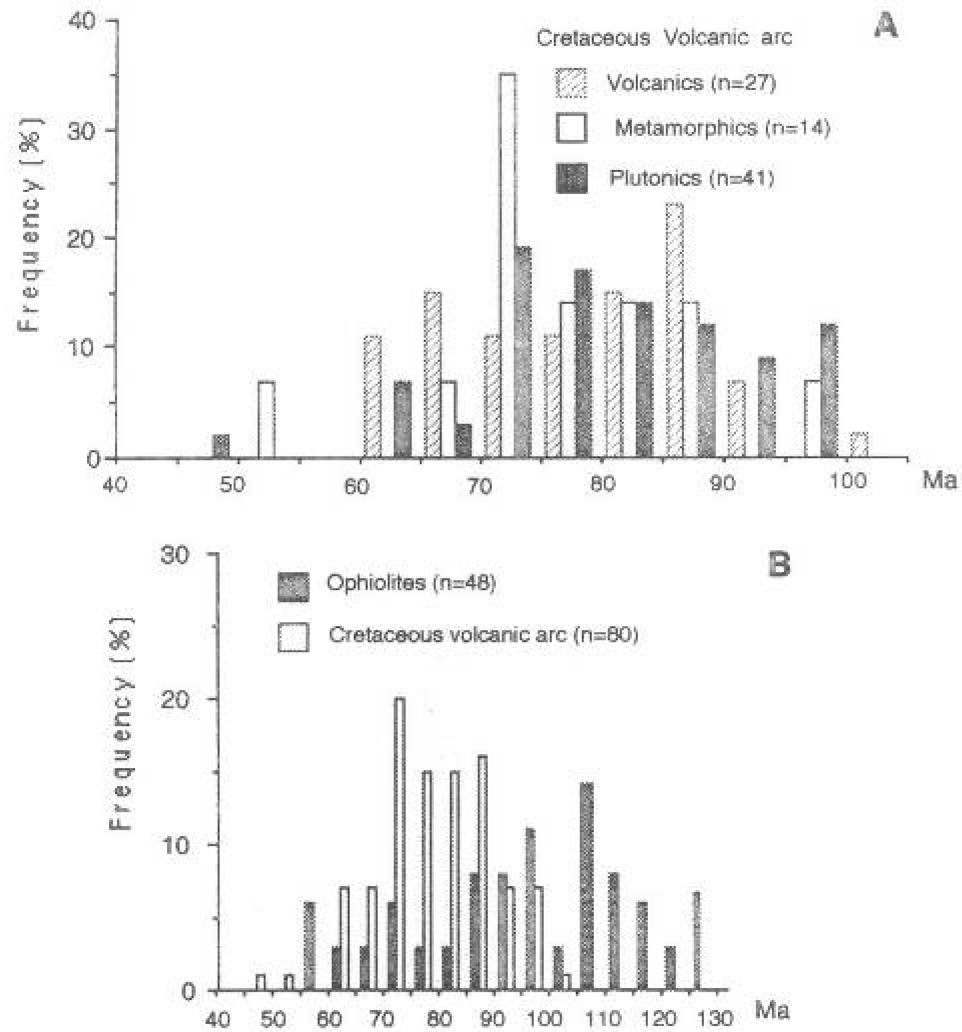

Figure 3. Histograms for the K-Ar ages from the Cretaceous volcanic arc (A) and combined the Northern ophiolites and the Cretaceous volcanic arc (B). Only values with error <10 %.

paleontologic data to identify their ages, except for a dubious finding of Mesozoic pollen and spores in the Mabujina amphibolites.

As is evident from Tables 8 and 9, the K-Ar ages in Mabujina range between 95±2 and 69±2 Ma (Upper Cretaceous) and only two samples were dated as Tertiary (52±1 and 44±5 Ma, Eocene-Oligocene).

The Escambray Terrane outcrops as a tectonic window surrounded by the Mabujina amphibolites, separated by a fault (Figure 1, Somin and Millán 1981). This situation is the result of the tectonic superposition of both of these geological units which originally occupied juxtaposed positions. The K-Ar ages of Mabujina generally coincide with those from the Escambray Terrane (Tables 4 and 8). This reflects the event of tectonic superposition of these units that took place during Latest Cretaceous, and the later cooling and uplift of the metamorphic core since Maastrichtian. Thus, K-Ar ages from Mabujina probably do not reflect the original low-P metamorphism of this complex, but the underthrusting of Escambray under Mabujina amphibolites, an event that took place at the end of the Cretaceous (Somin and Millán 1981).

The Guira de Jauco amphibolite complex outcrops in easternmost Cuba (Figure 1) and is a low-mid-P metaophiolitic unit (Somin and Millán 1981, Millán and Somin 1985a). The few K-Ar datings of the metamorphic rocks from this complex (Table 9) most probably reflect a tectonic event that took place after the metamorphism. Such a tectonic event could have been the overthrust of a tectonic sheet of the Cretaceous volcanic arc (Purial in Fig. 1), which also may have produced the high P/low T metamorphism that the Asunción and Guira de Jauco units exhibit (Figure 1). Geological evidence suggest that the thrusting took place during Maastrichtian-early Paleocene time (Nagy et al. 1983, Millán and Somin 1985a, Iturralde-Vinent 1989).

The same tectono-metamorphic event is also recognized in the Pinos and Escambray Terranes, and in the Mabujina and Guira de Jauco complexes. As a whole, this coincides in time with the general stage of deformation of the Cuban foldbelt, from latest Campanian to early Upper Eocene (76 to 45 Ma). All of these metamorphic rocks were usually interpreted as components of the crystalline basement of Cuba, but they are Mesozoic components of the Cuban foldbelt (Somin and Millán 1981).

The Cretaceous volcanic arc is the most thoroughly studied by the K-Ar method (Table 11). Paleontologic ages obtained from volcanic and sedimentary rocks of the arc range from Aptian (?)-Albian to Campanian (approximately 115?-105--75 Ma) which roughly correlates with the reliable K-Ar dates from the volcanic rocks (100,1±3,8 - 60,5±6 Ma; Table 11). This suggest that the isotopic ages are reflecting the magmatic events that took place during the evolution of the arc and are at most only slightly rejuvenated.

Plutonic rocks in the arc also have a wide range of ages, because granitoid clasts have been found in conglomerates of late Albian (100-97.5 Ma), Santonian (87.5 - 84 Ma) and late Campanian - Maastrichtian (76-65 Ma) age. The largest plutonic bodies cut the volcanic and sedimentary rocks as a whole, which indicate that the main intrusive event took place during the Campanian (Eguipko et al. 1984, Iturralde-Vinent et al. 1989). K-Ar ages from samples of plutonic rocks, reflect the same age span (99±6 - 49,5±3,5 Ma; Table 13). This is also true for the metagranitoids found within the Mabujina Complex (Table 9: 95±2 - 52±1 Ma). The overall average of 79 Ma (Campanian) for the plutonic rocks might be a good dating for the cooling of the main intrusive body. The hornfels, whose K-Ar ages agree well with those of the plutonic rocks, confirms this assertion (Table 14), as they are related with the contact metamorphism of the larger plutonic bodies.

Figure 3A illustrates the spectrum of K-Ar ages with errors ≤10 % obtained in the complexes that are components of the Cretaceous volcanic arc. It shows a peak at 70-75 Ma, which may reflects the cooling and uplift of the arc's magmatic chambers that took place since the end of the Campanian (Iturralde-Vinent et al. 1989).

Some authors have suggested the occurrence of minor intrusions in the Maastrichtian and early Eocene within the Cretaceous volcanic arc, based on the K-Ar datings of some plutonic rocks that display these ages (Fig. 3A). This is not necessarily true because the foldbelt suffered important deformations during the Maastrichtian-Eocene interval. It is thus more likely that these deformations are responsible for the rejuvenation of the K-Ar ages determined in Cretaceous rocks from the volcanic arc (Iturralde-Vinent et al. 1989). The same is true for many Mesozoic igneous and metamorphic rocks within other geologic units.

The general spectrum of the K-Ar ages obtained in the Cretaceous volcanic arc ranges from 100,1±3,8 (Cretaceous) to 49,5±3,5 (Eocene). In the ophiolites from the Northern belt and Guaniguanico Terrane, K-Ar ages range from 160±24 Ma (Jurassic) but mostly from 128±5 (Lower Cretaceous) to 52±6 Ma (Paleocene-Eocene). It is evident that there is only partial coincidence between the age ranges of the ophiolites and those of the volcanic arc (Figure 3B). In this figure, the lack of correspondence between largest peak of the datings in the volcanic arc (70-75 Ma) and the ophiolites (105-110 Ma) is remarkable. This suggest that both geologic units underwent different geological histories and are independent units as pointed out by Iturralde-Vinent (1989).

The Lower Cretaceous (or older?) high-P metamorphic events in the ophiolites antedates the Cretaceous volcanic arc, and probably are related to the early history of the Caribbean crust (Iturralde-Vinent 1994). Therefore, the ophiolites constitute an older geological unit than the volcanic arc and has consequently suffered the influence of more tectono-magmatic events.

Paleogene volcanic arc

The rocks belonging to this arc are present mostly in eastern Cuba (Nagy et al. 1983, Iturralde-Vinent 1990) and within its limits the following complexes can be recognized (Figure 1).

- volcanic and sedimentary (No datings)
- plutonics
- metamorphics (No datings)

The rocks from the volcanic-sedimentary complex have been dated by paleontologic methods as mid-Paleocene to early Middle Eocene (63-50 Ma). As the intrusive bodies cut all this section, the main intrusion must be younger than 50 Ma. Table 11 shows that the K-Ar ages vary between 58±8 and 39±4 Ma with an average of 47 Ma (Middle Eocene). This may be the age of cooling of the intrusion. Youngest ages (41,6±5 and 39±4 Ma) probably are related to Latest Eocene-Oligocene deformation and uplift of the arc due to tectonic deformations along the Oriente transcurrent fault.

There are some Cretaceous K-Ar ages (133±40 and 65±10 Ma; Table 11) identified in plutonic rocks from the Turquino area (Fig. 1). Although these ages are not accurate, they may reflect the fact that Cretaceous volcanic arc rocks outcrop in the same territory. Further sampling is necessary in this area.

K-Ar THERMAL EVENTS

Another possible approach for the interpretation of the K-Ar database is illustrated in Figure 4. It shows the frequency distribution of the reliable samples for the K-Ar age data <150 Ma. Ages older than 150 Ma are few and only add noise to the histogram. In order to check the internal consistency of the database, two subsamples were prepared, for errors of ≤5 % (n=106) and ≤10 % (n=186). Both curves are totally congruent (Fig. 4). A third statistical sample, for datings with errors ≤15 % is not ilustrated, because it includes determinations as young as Oligocene and Miocene, which lack geological basis, as Oligocene to Recent rocks were not sampled for K-Ar dating (Fig. 2).

The frequency histogram was prepared for a class interval equal to 5 Ma, because more than 70 deteminations have error ≤ ±5 Ma. The intention is to obtain a frequency histogram that would display the irregular distribution of the accepted values. With class intervals greater than 5 Ma, the curve is less detailed and information is lost. The interest is to distinguish irregularities in the curve and to assess the meaning of every peak. It will be demonstrated that most of these peaks reflect some thermal events (tectonic, magmatic and metamorphic) that affected the different geological units amalgamated in the Cuban foldbelt. The curve for datings with errors ≤ 10 % shows nine peaks (Fig. 4). Nevertheless, two more peaks are evident in ages older than 150 Ma, althought very few determinations are reliable for this interval.

Each of these peaks is represented by a number of ages that varies from 2 to 61. The large amount of determinations that correspond with the 65-75 Ma (n=61) interval is influenced by the high number of samples taken from the Cretaceous plutonic rocks of Cuba (n=74 as a whole), whose median value is 79. Nevertheless, this maximum does not represent an artifact of the sampling, because it is present in different geological units other than those from the Cretaceous volcanic arc. In fact, it coincides with an important deformation phase within the foldbelt.

The suspected K-Ar thermal events that correspond with important tectono-magmatic events in the geological history of the units that build up the Cuban foldbelt will be evaluated below.

Berrisian-Valanginian peak (135-145 Ma)

This peak corresponds with four K-Ar ages

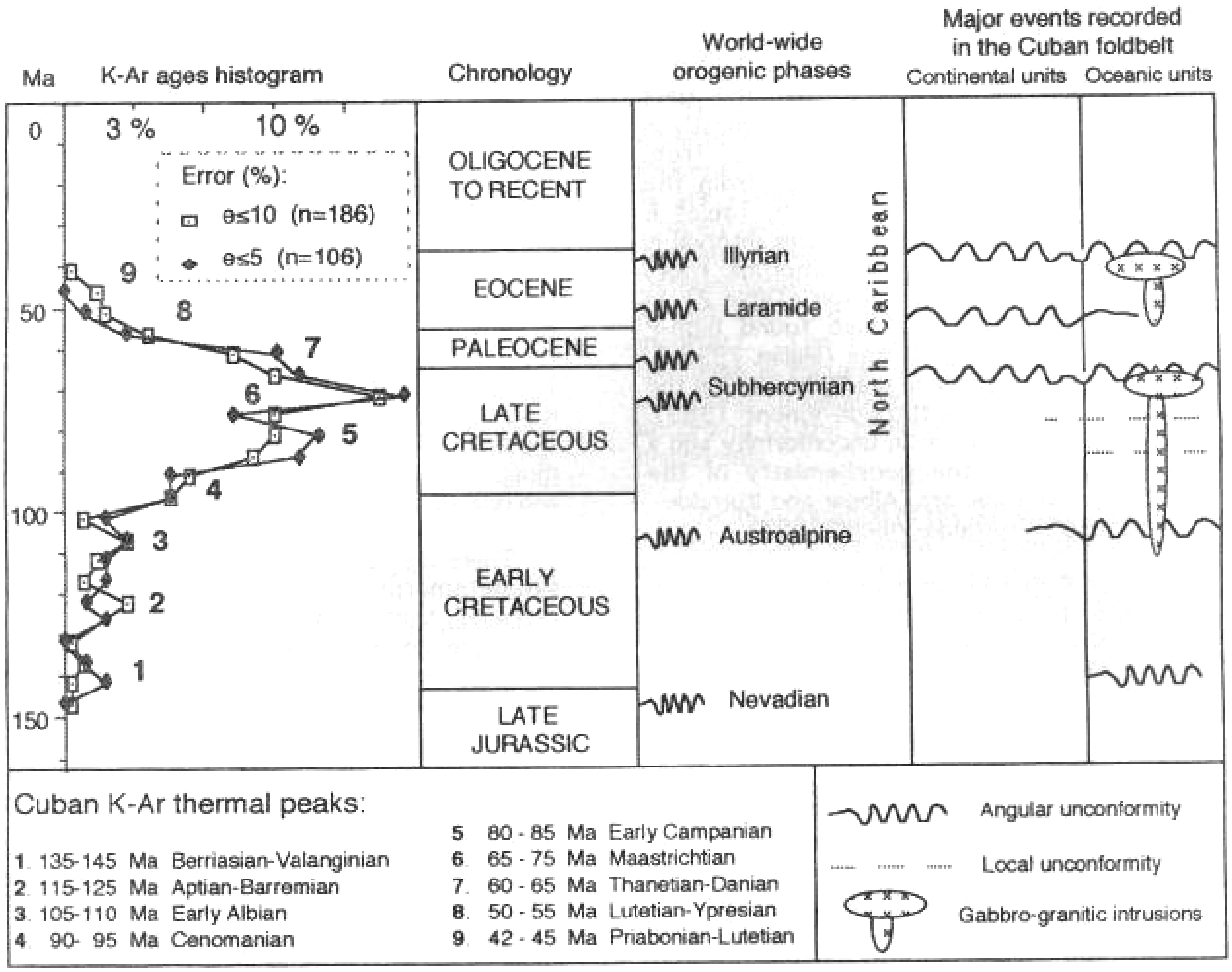

Fig. 4. K-Ar thermal peaks and its correlation with world wide tectonic events

in small granite intrusions of 172,4 Ma U-Pb age, that cut the sialic basement of the Bahamas (Figure 1, Table 1; Somin and Millan 1981, Renne et al. 1989). Therefore, this K-Ar peak is interpreted here as a rejuvenated older magmatic (thermal) event.

Aptian-Barremian peak (115-128 Ma)

These K-Ar ages are recognized mainly within the ophiolites in Guaniguanico and the Northern melange (Figure 3). They come from dolerites and gabbro-dolerites, and from blocks of high-P metaophiolites (n=12, Tables 6 and 7). Isolated ages within this peak are found in sialic metamorphic rocks of Guaniguanico and Bahamas (n=2, Tables 2 and 5).Some of these results may record the oceanic magmatism of the Caribbean crust since Lower Cretaceous basalts are known in Cuba (Andó et al. Chapter 2). However, the high-P metaophiolites probably correspond with a metamorphic event of this age or older.

Many authors believe that this event was the subduction of the Caribbean crust below the Cretaceous volcanic arc (Millán and Somín 1985b, Andó et al. 1989); but Iturralde - Vinent (in this chapter) presented the idea that this high-P metaophiolites were originated along a combined dip-slip plus strike-slip tectonic environment at the north Caribbean plate boundary. G. Millán believes that this metamorphic rocks can be related with the subduction (or underthrusting) of the Caribbean crust before the development of the volcanic arc.

Albian peak (105 - 110 Ma)

Various ages correspond with this time interval and they have been obtained mostly in blocks of high-P metaophiolites from Guaniguanico Terrane, as well as from the Northern ophiolitic melange (n=9, Tables 6 and 7). One isolated age from this interval is also found in a block of metamorphic rocks from the San Adrian salt diapir (Table 2). In Escambray Terrane are also found high-P eclogites with this U-Pb age (Millán 1992a). Albian basalts of this age are known within the Northern ophiolites (Iturralde-Vinent 1989). This is also the time of an unconformity and a major change in the geochemistry of the Cretaceous volcanic arc (Albear and Iturralde-Vinent 1985, Iturralde-Vinent 1994).

These K-Ar peak in high-P metaophiolites suggests the occurrence of a metamorphic events of roughly Albian or older age (Figure 3B), probably coincident with the modifications in the tectono-magmatic regime in the Cretaceous volcanic arc (Iturralde-Vinent 1994). This event can be the subduction of the ophiolites below the Cretaceous volcanic arc (Millán and Somin 1985a, Andó et al. 1989). But according to several authors (i.e.: Pindell and Barrett 1990), during the Albian took place a reverse in the direction of subduction. These are possible explanations for this peak, but an alternative hypothesis according to the senior author, is that these events are a regional counterpart of the world-wide Austroalpine tectonic movements. In this context, the high-P metamorphism can be related to the compresional stress field located along the north Caribbean plate boundary (Iturralde-Vinent 1994).

Cenomanian peak (90-96 Ma)

This peak is represented in the high-P metamorphic rocks of the northern ophiolites (Table 6, n=4), and the Guaniguanico Terrane (Table 7, n=4), and most of all, in the vulcanic and plutonic rocks of the Cretaceous arc (n=9, Tables 9, 12, 13; Figure 3B). Tholeiitic magmatism of this age has been described in the Northern ophiolites, isochronous with calc-alkaline magmas within the Cretaceous arc (Khudoley and Meyerhoff 1971, Kozák et al. 1989, Iturralde-Vinent 1989). This suggests that igneous activity could contribute to this K-Ar peak (Figure 4), but also high-P metamorphism within the north Caribbean plate boundary.

Campanian peak (80-85 Ma)

These K-Ar ages were determined in rocks with different kind of metamorphism found as blocks in the ophiolites (n=3, Table 6), in mafic high-T metamorphic rocks of the Mabujina complex (n=3, Table 8) and moreover, in igneous and high-T metamorphic rocks of the Cretaceous volcanic arc (n=13, Tables 9, 12, 13, 14; Figures 3 and 4). This K-Ar thermal event is very likely to reflect the final volcanism within the volcanic arc and most of all, the last main episode of intrusion and related contact metamorphism.

There are few K-Ar ages of this time from synmetamorphic veins of the Escambray terrane, that may be interpreted as a consequence of some tectono-metamorphic thermal event. This ages may also be related with the greenschist facies metamorphism in the Escambray Terrane due to an important collisional event (Millán 1992a).

Maastrichtian peak (65-75 Ma)

This K-Ar peak is very important because the largest number of ages fall within it. Also an angular unconformity of regional character, located between the Maastrichtian and the Campanian, correlates with this peak and probably reflects the beginning of important deformation within the Cuban foldbelt (Khudoley and Meyerhoff 1971, Pszczolkowski and Flores 1986). This is evident since the K-Ar peak is recognized in the Guaniguanico (n=3, Table 5), the Pinos (n=8, Table 3) and Escambray (n=3, Table 4), in the ophiolites (n=3, Table 6), in the Mabujina (n=6, Tables 8 and 9), and Guira de Jauco (n=2, Table 10) and in the different elements of the Cretaceous volcanic arc (n=21, Tables 12 and 13). Therefore, the Maastrichtian peak may be considered mainly of tectonic nature related with the orogenic movements within the Caribbean. This event is a regional counterpart of the Subhercynian movements (Fig. 4) and mark the begining of a longer tectonic period that Pszczolkowski and Flores (1986) named the NorthCaribbean orogeny.

Thanetian-Danian peak (60-65 Ma)

This peak is recorded mainly in the Cretaceous volcanic arc (n=7, Tables 12 and 13) and in the Pinos terrane (n=4, Table 3), but isolated ages are spread withion the other geologic units of the foldbelt. The end of the Danian coincides with the origin of a new volcanic arc in eastern Cuba (Figure 1, Nagy et al. 1983). In the Guaniguanico terrane, the Bahamas continental slope deposits and in the basins that evolved on top of the extinct Cretaceous arc a regional unconformity is recognized at the K/T boundary, which often includes a Danian hiatus (Khudoley and Meyerhoff 1971, Pardo 1975, Pszczolkowski and Flores 1986). Conse-quently, the K-Ar peak of 60-65 Ma correlates with the beginning of a new arc and with deformation in several units of the foldbelt.

Lutetian-Ypresian peak (50-55 Ma)

This event is represented in different terranes by local disconformities and changes in sedimentation patterns, and correlates with the end of extrusive magmatism in the Paleogene arc. Few rocks with this K-Ar age are found within the different units represented in the foldbelt. It seems to be a major tectonic event throughout the Caribbean, and correlate with the Laramide orogenic movements world wide (Fig. 4).

Priabonian-Lutetian peak (42-45 Ma)

This peak coincides in time with a regional unconformity within the Upper Eocene (rougly Illyrian movements, Fig. 4) that marks the last important deformation and the consolidation of the foldbelt. After this time, a new tectonic style (neoautochthonous) began in the Cuban territory (Iturralde-Vinent 1978). The K-Ar ages of this time are sparse and evident in few geological units (Escambray, Mabujina and Paleogene arc).

CONCLUSIONS

A new database is summarized with more than 300 isotopic age determinations of Cuban samples. The most common technique used is the K-Ar method (n=267). These ages are evaluated as an alternative approach to the geological interpretation of Cuba. To accomplish this the K-Ar datings were grouped into geologic units identified according to genesis and composition.

The K-Ar database comprises age determinations ranging from Late Proterozoic to Miocene. However, if datings with errors >10 % are eliminated, remaining ages (n=189) concentrate within the Late Proterozoic, Jurassic, Cretaceous, Paleocene and Eocene. Determinations of Paleozoic, and Oligocene to Recent ages are questionable and generally incorrect. The interpretation of the K-Ar database is focused in two directions: one, according to geological units and the other, according to the peaks found in a frequency histograms.

The interpretation of the database according to geological units shows that all datings are from samples of the geological units that comprise the Cuban foldbelt that yield Late Eocene and older rocks. The foldbelt encompasses both continental and oceanic units.

In the continental units (Bahamas platform, Guaniguanico, Pinos and Escambray terranes), the oldest rocks belong to the Bahamas basement (945±20 - 910±25 Ma) which reflect a Grenville event. Jurassic K-Ar ages (150±5 - 139±6 Ma) are also found within igneous rocks of the Bahamas platform, ages that agree with magmatism that took place in the passive continental margin environment. The Pinos and Escambray terranes, built up by metamorphic rocks, yield K-Ar ages from Late Cretaceous to Eocene (85±4 - 43±5 Ma). These ages reflect the last metamorphic event and later uplift of both massifs.

In the oceanic units (Northern ophiolites, Cretaceous volcanic arc and Paleogene volcanic arc), the oldest rocks are found in the Northern ophiolites (160±24 Ma). Also the oldest oceanic metamorphic rocks belong to these ophiolites (128±5 - 126,3±8,3 Ma). The wide range of ages in the ophiolites (160±24 - 52±6 Ma) is the result of the combined action of magmatic and tectono-metamorphic events. Rocks of the Cretaceous volcanic arc display generally younger ages than the ophiolites (100,1±3,8 - 49,5±3,5 Ma), a fact suggesting that both geological units have evolved somehow individually. K-Ar ages from the Cretaceous volcanic arc reflect both magmatic and tectonic events. The last important magmatic event in the arc is the intrusion of the main plutonic body during Campanian, whose K-Ar cooling age is estimated as 79 Ma. Maastrichtian to Eocene K-Ar ages of arc rocks are probably due to tectonic avents. K-Ar dating for the Paleogene volcanic arc are all from the plutonic bodies. The K-Ar age of the intrusion cooling is estimated as 47 Ma, with younger ages (41,6±5 - 39±4 Ma) probably representing tectonic deformations.

The overall evaluation of the K-Ar ages with errors ≤ 10 % shows that most of the results are clustered around a maximum of 65-75 Ma, a datum that represents the extinction of the Cretaceous volcanic arc and an important change in the evolution of the western Caribbean. A minimum of 9 peaks are evident in the K-Ar frequency histogram. Most of these peaks correlate in time with important magmatic, metamorphic and/or tectonic events in the history of the geological units accreted in the Cuban foldbelt.

TABLES

Table 1. K-Ar ages of Socorro Complex, Villa Clara .

Rock	Material	Locality	Age (Ma)	Error(±)	Error (%)
Calciphire	Phlogopite	Socorro	945	20	2,6
Calciphire	Phlogopite	Socorro	910	25	2,7
Granite	WR (1)	Sierra Morena	150	5	3,3
Granite	Feldspar	Corralillo	142	3	2,1
Granite	WR	Cañas river	140	2	1,4
Granite	WR	Cañas river	139	6	4,3

(1) WR: whole rock

Table 2. K-Ar ages from suspected pre-Mesozoic sialic rocks found as inclusions in the Northern ophiolites (OF) and in the San Adrián (SA) salt diapir.

Rock	Material	Province	Age (Ma)	Error (±)	Error (%)
(OF) Gneiss A	Moscovite	Holguín	196,5	8	4,1
(SA) Phlogopite marble	Phlogopite	Matanzas	123	5	4
(SA) Crystalline schist	WR	Matanzas	109	8	7,3
(OF) Gneiss A	Feldspar	Holguín	91,1	3	3,3

Table 3. K-Ar ages from Pinos Terrane. Median value in bold.

Rock	Material	Age (Ma)	Error (±)	Error (%)
Moscov. schist	Moscovite	78	4	5,1
Greisen (vein)	Moscovite	78	4	5,1
Mica schist	Moscovite	76	2	2,6
Greisen	Moscovite	73	4	5,5
Moscov. schist	Moscovite	73	4	5,5
Greisen (vein)	Moscovite	72	3	4,1
Mica schist	Moscovite	67	3	4,5
Mica schist	Biotite	66	3	4,5
Schist	Biotite	66	3	4,5
Greisen (vein)	Moscovite	66	4	6,1
Crystalline schist	Biotite	**65**	4	6,2
Tremol.-mica schist	Moscovite	64	3	4,7
Mica schist	Mica	64	2	3,1
Schist	Moscovite	60	3	5
Schist	WR	60	3	5
Moscovite schist	Moscovite	55	3	5,5
Schist	Moscovite	52	3	5,8
Amphibolite	WR	49,3	3,8	7,7

Table 4. K-Ar ages from Escambray Terrane. Median value in bold.
Underlined doubtful determinations.

Rock	Material	Age (Ma)	Error (±)	Error (%)
Eclogitic rock A	Hornblende	255	7	2,7
Blue schist A	Glaucophane	210	13	6,2
Eclogitic rock	Mica	103	28	27.2
Synmetamorphic vein	Moscovite	85	4	4,7
Synmetamorphic vein	Moscovite	80	6	7,5
Synmetamorphic vein	Moscovite	76	4	5,3
Synmetamorphic vein	Moscovite	74	3	4
Eclogitic rock A	Paragonite	75	4	5,3
Apoeclogite	Moscovite	73	5	6,8
Eclogite	Paragonite	73	4	5,5
Glaucoph-mica schist	WR	68	8	11,8
Metabasite	Paragonite	68	2	2,9
Blue schist A	Phengite	68	1	1,5
Blue schist B	Phengite	**66**	1	1
Mosc-Q schist	Moscovite	66	4	6,6
Eclogitic rock	Moscovite	65	5	7,7
Mosc-calc schist	Moscovite	61	4	6,6
Mosc-calc schist	Moscovite	60	3	5
Glauc-mica schist	WR	58	2	3,4
Blue schist B	Glaucophane	56	3	5,4
Synmetamorphic vein	Feldspar	54	3	5,5
Amph-mica schist	Hornblende	43	5	11,6

Table 5. K-Ar ages of sialic rocks from Guaniguanico Terrane. Also gneiss from the Lower Eocene conglomerate near El Guayabo (GA).

Rock	Material	Age (Ma)	Error (±)	Error (%)
Sericitic schist	WR	196	8	4,1
Seric.-Q schist	WR	119	10	8,4
(GA) Gneiss	WR	71	3	4,2
(GA) Gneiss	Moscovite	70,5	1,4	2
(GA) Gneiss	WR	55	6	10.9

Table 6. K-Ar ages from mafic rocks in the Northern ophiolites. Underlined doubtful values. (&) Low-P metaophiolites, (*) High-P metaophiolites.

Rock	Material	Region	Age (Ma)	Error (±)	Error (%)
Anorthosite (1)	WR	Camagüey	160	24	15
Dolerite	WR	Holguín	126,3	8,3	6,5
Gabbro-dolerite	WR	Holguín	120,3	9	7,4
Dolerite	WR	Holguín	102	20	19,6
Dolerite	WR	Holguín	98,2	5	5
Basalt	WR	Holguín	91,2	3,6	3,9
Basalt	WR	Holguín	86,7	3,5	4
Basalt	WR	Holguín	83	9	10,8
Plagiogranite	WR	Villa Clara	79	5	6,3
Basalt	WR	Holguín	73	3,3	4,5
Diabase	WR	Holguín	72,4	2,8	3,8
Monzonite		S. Spiritus	61	1,8	3
Amph. gabbrodiabase	WR	Mayarí-Bcoa	60	10	16,6
Dolerite	WR	Holguín	57,8	5,4	9,3
&Metagabbroid		Villa Clara	82	4	4,8
&Metagabbroid	WR	Pinar del Río	72	14	19,4
&Metagabbroid	Amphibole	Holguín	68,2	3,5	5,1
*Eclogitic rock B	Piroxene	Matanzas	450	50	11,1
*Eclogitic rock B	Moscovite	Matanzas	126	10	7,9
*Garnetamphibolite	Moscovite	Holguín	125	12	9,6
*Synmet. vein A	Moscovite	Mayarí-Bcoa	125	5	4
*Garnet amphib.	Moscovite	Holguín	119		
*Synmet. vein	Moscovite	Mayarí-Bcoa	119	11,9	10
*Garnet amphibolite	Hornblende	Guantánamo	116	9	7,7
*Eclogitic rock C	WR	Pinar del Río	115	5	4,3
*Eclogite D	WR	Pinar del Río	112	4	3,6
*Eclogite D	Mica	Pinar del Río	110	5	4,5
*Garnet amphib.	Amphibole	Holguín	109		
*Eclogitic rock C	Mica	Pinar del Río	108	3	2,8
*Eclogitic rock A	Mica	Holguín	105	5	4,8
*Eclogitic rock A	WR	Holguín	105	3	2,9
*Eclogitic rock B	Amphibole	Matanzas	105	10	9,5
*Mica-Q schist	WR	Mayarí-Bcoa	104	12	11,5

*Eclogitic rock	Amphibole	Holguín	103	5	4,8
*Eclogitic rock	Amphibole	Holguín	103		
*Synmet. vein A	Moscovite	Mayarí-Bcoa	96	4	5,2
*Garnet amphibolite	WR	Villa Clara	91	9	9,8
*Eclogite D	Amphibole	Pinar del Río	91	17	18,7
*Eclogitic rock A	Amphibole	Holguín	91	6	6,6
*Eclogitic rock C	Amphibole	Pinar del Río	90	5	5,5
*Q-mosc. schist	WR	Guantánamo	88	7	7,9
*Garnet amphibolite	WR	Guantánamo	83	10	12
*Q-mica schist	WR	Mayarí-Bcoa	67	7	10,4
*Garnet amphibolite	WR	Villa Clara	64	12	18,7
*Garnet amphibolite	WR	Villa Clara	60	12	20
Mosc.-Q schist	WR	Villa Clara	52	6	11,5

(1): This age is acceptable because agree with the general age span of the ophiolites as was discussed by Somin and Millán (1981) and Iturralde-Vinent (1989)

Table 7. K-Ar ages from high-P meta-ophiolites found as inclusions in the Lower -Middle Eocene olistostrome, Guaniguanico Terrane. Underlined doubtful values.

Rock	Material	Age (Ma)	Error(±)	Error (%)
Eclogitic rock A	Amphibole	247	20	8,1
Blue schist	WR	128	5	3,9
Eclogite	Moscovite	115	5	4,3
Eclogitic rock A	Moscovite	110	10	9,1
Garnet amphibolite	WR	105		
Eclogitic rock A	WR	96	4,8	5
Garnet amphibolite	Hornblende	95	12	12,6
Garnet metasilicite	WR	87	5	5,7
Eclogitic rock	WR	81	30	37
Eclogitic rock	WR	58	5	8,6
Eclogitic rock	WR	58	2	3,4

Table 8. K-Ar ages from mafic rocks of Mabujina Complex. Underlined low precision doubtful values.

Rock	Material	Age (Ma)	Error (±)	Error (%)
Amphibolite		222,7	44,4	19,9
Amphibolite	Hornblende	198,7	41,6	20,9
Amphibolite	WR	89	3	3,3
Amphibolite	WR	87,8	1,8	2
Amphibolite	WR	87	1,7	2
Amphibolite	Amphibole	81,2	1,6	2
Amphibolite	Amphibole	80,9	1,6	2
Amphibol. schist	Amphibole	80,7	1,6	2
Amphibolite	Hornblende	77	8	10,4
Hornblendite	WR	76	10	13
Pegmat. amphib.	Hornblende	72	7	9.7
Amphibolite	Hornblende	44	5	11,4

Table 9 K-Ar ages from sialic rocks of Mabujina Complex. These are probable metamorphosed plutonic rocks of the Cretaceus volcanic arc.

Rock	Material	Age (Ma)	Error (±)	Error (%)
Metagranitic gneiss A	Hornblende	95	2	2
Pegmatitic vein	Moscovite	84	1	1,2
Metagranitic gneiss B	Hornblende	84	3	3,5
Metagranitic gneiss C	Hornblende	78	3	3,8
Metagranitic gneiss B	Biotite	73	1	1,3
Orthogneiss D	Hornblende	73	2	2,7
Orthogneiss D	Biotita	73	2	2,7
Pegmatitic vein	Moscovite	72	5	6,9
Metagranitic gneiss A	Biotite	70	1	1,4
Metagranitic gneiss C	Biotite	69	2	2,8
Orthogneiss	WR	52	1	1,9

Table 10. K-Ar ages from Guira de Jauco Complex.

Rock	Mineral	Age (Ma)	Error (±)	Error (%)
Pegmatitic vein	Moscovite	72	3	4,2
Amphibolite	WR	65	0	0
Amphibolite	WR	62	5	8,1
Amphibolite	Amphibole	58	4	6,9

Table 11. K-Ar median values of the ages from Cretaceous volcanic arc rocks mostly with error ≤10% and a few selected with error <15%. Metamorphic complex include hornfels and regional metamorphic rocks.

Complex	Samples	Maximum	Minimum	Median value
Volcanics	27	100,1 ±3,8	60,5 ±6	78
Plutonics	51	99,0 ±6	49,5 ±3,5	79
Metamorphics	13	95,0 ±2	69,0 ±2	79

Table 12. K-Ar ages from Cretaceous volcanic rocks.

Rock	Material	Region	Age (Ma)	Error (±)	Error (%)
Ryolite	WR	Holguín	100,1	3,8	3,8
Liparite	WR	Villa Clara	95	9	9,4
Traquiandesite	WR	Holguín	91,5	4,5	4,9
Andesite	Feldspar	Holguín	90,9	4,3	4,7
Ryolite	WR	Holguín	87,4	3,3	3,8
Dacite	WR	Holguín	87,4	3,4	3,9
Andesite-dacite	WR	Camagüey	87	7	8
Andesite	WR	Holguín	86,1	4,5	5,2
Andesite	Amphibole	Holguín	85,3	3,3	3,9
Traquite	WR	Camagüey	85	5	5,9

Basalt	WR	Camagüey	83	5	6
Andesite-dacite	Biot.+Amph.	Holguín	82,8	3,3	4
Andesite	WR	Holguín	81,2	3,3	4,1
Dacite	WR	Camagüey	79	4	5,1
Liparite		Villa Clara	78	10	12,8
Andesite-dacite	WR	Holguín	76,6	3,1	4
Andesite	WR	Camagüey	75	5	6,7
Dacite	WR	Holguín	73,2	2,8	3,8
Andesite	WR	Holguín	72	3	4,2
Andesite-basalt	WR	Holguín	71,8	3,2	4,5
Andesite-basalt	WR	Holguín	69,2	2,7	3,9
Andesite-basalt	WR	Holguín	69,2	2,7	3,9
Andesite-dacite	Amphibole	Holguín	69,2	2,7	3,9
Andesite-dacite	WR	Holguín	66,8	2,7	4
Andesite-basalt	WR	Holguín	66	2,8	4,2
Tuff	WR	Holguín	65,9	3,9	5,9
Ryodacite	WR	Camagüey	63,5	2,5	3,9
Andesite	WR	Holguín	61,3	2,3	6,8
Andesite	WR	Holguín	60,5	6	9,9
Liparite		Villa Clara	53	6	11,3

Table 13. K-Ar ages from Cretaceous plutonic rocks. Underlined doubtfull values.

Rock	Material	Region	Age (Ma)	Error (±)	Error (%)
Tonalite	Biotite	Villa Clara	194,5	46,5	23,9
Diorite	WR	Villa Clara	180	18	10
Diorite	WR	Camagüey	130	49	37,7
Monzonite Q (C)	WR	Villa Clara	121,4		
Monzonite Q (C)	Hornblende	Villa Clara	102.8		
Diorite Q		Villa Clara	100		
Granodiorite (B)	Biotite	Villa Clara	100		
Sienite	WR	Camagüey	99	6	6,1
Sienite	Biotite	Camagüey	98,6	6	6,1
Sienite	Biotite	Camagüey	96,1	0,9	0,9
Sienite Q	WR	Camagüey	95	4	4,2
Granodiorite	Biotite	Villa Clara	93	5	5,4
Diorite Q (A)	Biotite	Villa Clara	92,3	1,9	2,1
Granite	WR	Camagüey	91	5	5,5
Granite	WR	Camagüey	91	5	5,5
Diorite Q	Biotite	Camagüey	89	4	4,5
Plagiogranite	WR	Villa Clara	89	20	22,5
Granodiorite	Biotite	Villa Clara	88	4	4,5
Diorite Q (A)	Amphibole	Villa Clara	86,3	1,8	2,1
Granodiorite		Camagüey	86	10	11,6
Granodiorite		Las Tunas	86	10	11,6
Sienite	K Feldspar	Camagüey	86	15	17,4
Diorite Q	Hornblende	S. Spiritus	85	1	1.1

Granodiorite	Biotite	Camagüey	85	4	4,7
Diorite Q		Villa Clara	84	4	4,8
Granodiorite	WR	Camagüey	84	4	4,8
Diorite Q	WR	Villa Clara	84	8	9,5
Tonalite		Bartlett Deep	83	2	2,4
Diorite	Amphibole	Holguín	82,8	6,4	7,7
Granodiorite (B)	Biotite	Villa Clara	82		
Diorite Q	WR	Villa Clara	82	10	12,5
Diorite Q	WR	Villa Clara	82	10	12,5
Granodiorite dike		Camagüey	81	4	4,9
Pegmatite		Camagüey	80	3	3,8
Granodiorite dike	Biotite	Camagüey	79	7	8,9
Diorite	WR	Camagüey	78	7	9
Diorite	WR	Holguín	77	10	13
Monzonite	Biotite	Camagüey	77	3	3,9
Granodiorite (B)	Biotite	Villa Clara	77		
Aplite		Camagüey	76	4	5,3
Monzonite Q (C)	Biotite	Villa Clara	76		
Diorite	Feldspar	Holguín	75,6	3,5	4,6
Sienite	Biotite	Camagüey	75	3	4
Granodiorite	WR	Camagüey	75	3	4
Trondjemite	Feldspar	Holguín	74,1	4,4	5,9
Granodiorite	WR	Villa Clara	74	10	13,5
Plagiogranite		Camagüey	73	3	4,1
Granodiorite		Villa Clara	73	10	13,7
Diorite Q	WR	Camagüey	72	3	4,2
Plagiogranite		Camagüey	72	7	9,7
Sienite	Hornblende	Camagüey	71,6	0.3	0.4
Diorite Q	WR	Camagüey	71	5	7
Granodiorite (B)	Feldspar	Villa Clara	70	4	5,7
Granodiorite	WR	Camagüey	70	4	5,7
Granodiorite		Camagüey	69	4	5,8
Diorite	WR	Villa Clara	69	14	20,3
Granite		Camagüey	64		
Diorite	WR	Holguín	61,1	2,4	3,9
Monzonite Q (C)	Biotite	Villa Clara	61		
Granodiorite		Camagüey	61	0,5	0,8
Granodiorite		Camagüey	61	5	8,2
Diorite	WR	S. Spiritus	59	7	11,9
Granodiorite		Camagüey	58	6	10,3
Granodiorite (B)	Biotite	Villa Clara	49,5	3,5	7,1

Table 14. K-Ar ages from metamorphic rocks (hornfels and metasomatic alterations) related with plutons of the Cretaceous volcanic arc.

Rocks	Material	Province	Age (Ma)	Error (±)	Error (%)
Metasomatic rock	WR	Camagüey	89	8	9
Amphibolite	WR	Camagüey	81	8	8,9
Metasomatic rock	WR	Camagüey	76	3	3,9
Hornfel schist	WR	Camagüey	57	2	3.5

Table 15. K-Ar ages from plutonic rocks of the Paleogene volcanic arc (Sierra Maestra) Median value in bold. Doubtful values underlined.

Rock	Material	Locality	Age (Ma)	Error (±)	Error (%)
Granitoid	Albite	Turquino	133	40	30,1
Granitoid	Plagioclase	Turquino	65	16	24,6
Diorite	WR	Nima Nima	58	8	13,8
Diorite	Biotite	Daiquirí	54,2	5	9,2
Diorite Q	WR	Daiquirí	49	6	12,2
Granodiorite		Santiago	47	4	8,5
Plagiogranite	WR	Nima Nima	46	6	13
Diorite	Biotite	Daiquirí	44	4	9,1
Diorite	Biotite	Nima Nima	41,6	5	12
Diorite	Biotite	Daiquirí	39	4	10,2