GEOLOGIC SIGNIFICANCE OF RADIOMETRIC DATES FROM CUBA

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Geologic Significance of Radiometric Dates from Cuba[1]

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Abstract Nine radiometric dates from Cuba indicate that at least two thermal events have affected the island. One is 103–121 m.y. old (Neocomian-Cenomanian), and may correspond to an Early to middle Cretaceous orogeny, the evidence for which is well established by field mapping. Probably most of the granodioritic plutons of central and western Cuba are Early to middle Cretaceous, though more dates are needed to prove their age. A 180-m.y. date (Early Jurassic) from southern Las Villas Province does not fit the known history of Cuba, and its significance is not understood.

Dates ranging from 61 to 78 m.y. (Campanian-early Paleocene) in the central and western parts of Cuba may reflect the onset of Campanian-Eocene orogeny, which culminated with the intrusion, 46–58 m.y. ago (late Paleocene–middle Eocene), of quartz diorite batholiths and stocks in southern Oriente Province, eastern Cuba.

Except for the 180-m.y. date, the history of thermal events shown by the radiometric dates is similar to that of the Greater Antilles geosyncline (island arc) east of Cuba—from Jamaica and Hispañola to the Virgin Islands.

Introduction

Knowledge of Cuban geology, despite extensive geologic and geophysical studies, still is very incomplete, and numerous major problems are unsolved. To solve some of these problems, U. S. and USSR geologists collected several specimens for radiometric dating. Although most of the dates which were determined have been published (Table 1), some were reported erroneously, and others are in literature which is difficult to obtain. The purposes of this note are to correct the errors which have been published, to publish in one place the dates that have been determined, and to relate the dates to Cuba's geologic history.

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Summary of Cuban Geologic History

Much of Cuba is underlain by continental crust which is believed to be a southern extension of the Florida basement (Soloviev *et al.*, 1964). The Florida basement has been affected by thermal events as old as Early Ordovician to Early(?) Cambrian (Bass, 1969; Milton and Grasty, 1969, this issue of *Bulletin*). However, the age of the Cuban "basement" is unknown, and extrapolation to Cuba of ages obtained in Florida is risky.

The oldest Cuban rocks dated paleontologically are Early through Middle Jurassic (Imlay, 1964; Judoley and Furrazola, 1968; Krömmelbein, 1956; Vachrameev, 1966). They are a sequence of nonmarine(?) strata which contain some beds bearing marine fossils—the San Cayetano Formation, northern Pinar del Río Province, western Cuba (Fig. 1). Equivalent strata probably include certain very low-grade metamorphic rocks of the Isle of Pines, the Sierra de Trinidad (Las Villas Province), and eastern Oriente Province. The Punta Alegre Formation (Fig. 1) of the Cuban north coast (from Matanzas Province to Camagüey Province) consists of evaporite deposits (mainly halite), and may be partly equivalent to the San Cayetano (Meyerhoff and Hatten, 1968). The Punta Alegre Formation is known only from salt domes, and contains Jurassic spores (Meyerhoff and Hatten, 1968). A generalized reconstruction of the Early and Middle Jurassic paleogeography of Cuba is shown in Figure 2.

Certain low- to high-grade metamorphic rocks of the Isle of Pines (Kuman and Gavilán, 1965), Sierra de Trinidad (Furrazola *et al.*, 1964, 1968; Hill, 1959; Khudoley, 1967a, b; Meyerhoff and Hatten, 1968; Thiadens, 1937), east-central Las Villas Province, Jarahueca area (Hatten, 1967; Meyerhoff and Hatten, 1968), and eastern Oriente Province (Furrazola *et al.*, 1964, 1968) have been referred to both the Jurassic and Paleozoic. Khudoley (1967a, b) wrote that the metamorphic rocks of Cuba are equivalent to the San Cayetano Formation. Hatten (1967) disputed this, and argued that the metamorphic rocks of Cuba are

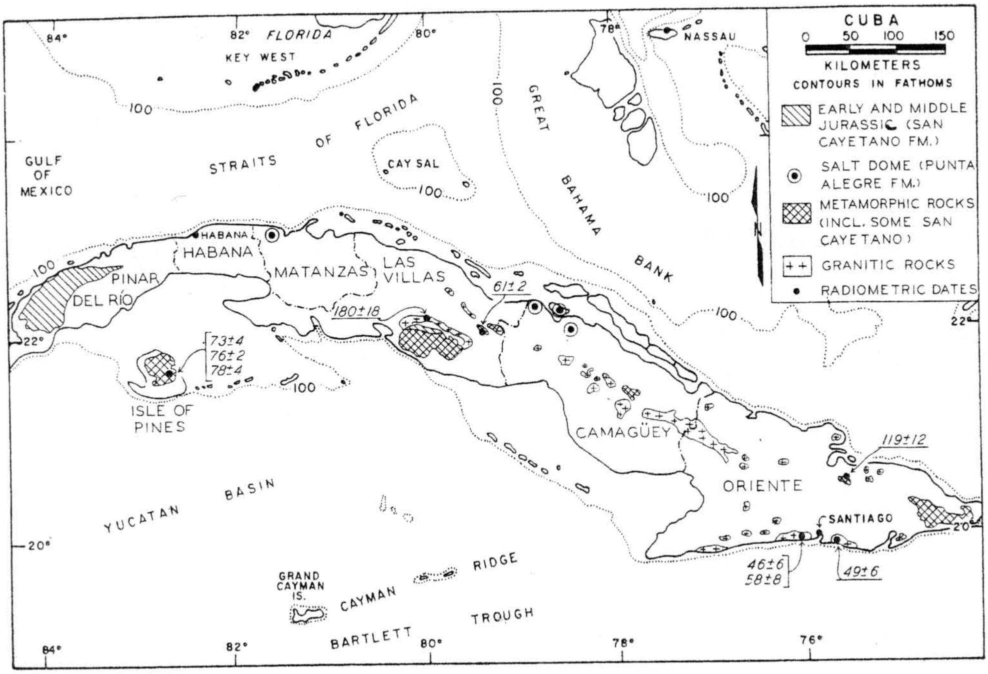

FIG. 1.—Index map of Cuba. Shown are outcrops of Early and Middle Jurassic San Cayetano Formation, metamorphic rocks of Jurassic(?) and Paleozoic(?) ages, salt domes of Jurassic Punta Alegre Formation, granitic plutons, and radiometric dates.

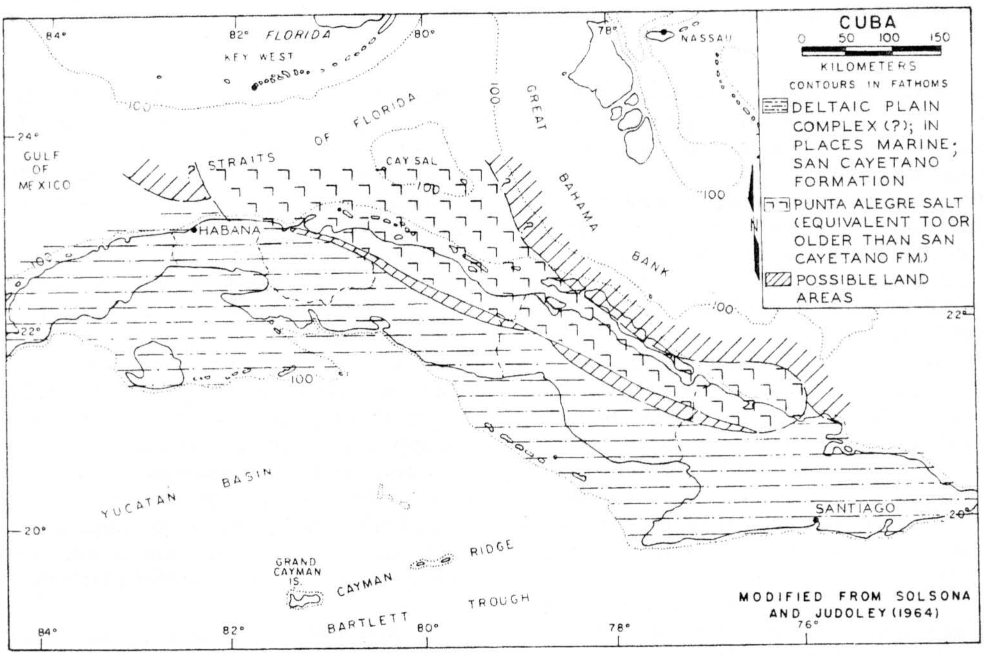

FIG. 2.—Generalized map to show areas where pre-Tithonian Jurassic formations of Cuba were deposited. Punta Alegre Formation (salt) is believed to be equivalent to, or older than, San Cayetano. Taken from Solsona and Judoley (1964) and Meyerhoff and Hatten (1968).

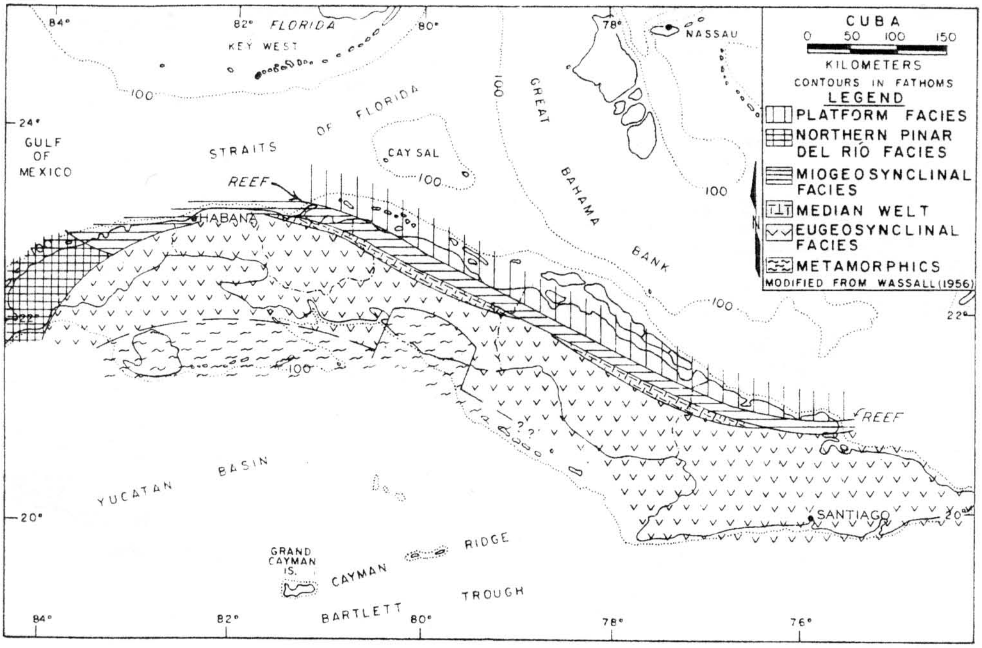

FIG. 3.—Generalized paleotectonic map for Tithonian (or Aptian) to Turonian (latest Jurassic to early Late Cretaceous) time in Cuba. Shows disposition of various units within orthogeosyncline. Platform facies is Bahama platform, Old Bahamas Channel, Cayo Coco, and Remedios facies-structural zones of Khudoley (1967a) and Khudoley and Meyerhoff (1968); miogeosynclinal facies and median welt comprise Las Villas facies-structural zone of Khudoley (1967a) and Khudoley and Meyerhoff (1968); eugeosynclinal facies includes Zaza, Nicaro-Moa, and Cauto facies-structural zones of Khudoley (1967a) and Khudoley and Meyerhoff (1968). Modified from Wassall (1956) and Meyerhoff and Hatten (1968).

pre-Jurassic, probably Paleozoic. Tijomirov (1967) presented a strong argument for a Paleozoic age. The entire problem—*pro* and *con*—is reviewed by Khudoley and Meyerhoff (1968). Radiometric dating of these rocks has not been successful, and a complete reconstruction of Cuban geologic history requires that they be dated. The age of the metamorphic rocks remains one of the major unsolved problems of Cuban geology.

The Jurassic San Cayetano Formation and its equivalents are overlain in western Cuba by a marine Callovian(?), Oxfordian, Kimeridgian, and Tithonian terrigenous clastic and carbonate sequence. Equivalent Callovian(?)-Kimeridgian strata probably are present elsewhere in Cuba; the Tithonian is widespread, particularly along the Cuban north coast east of Habana (Fig. 3).

Between Tithonian and Aptian times, a geosyncline formed from westernmost Cuba to the Virgin Islands (Fig. 3). Hatten (1967) and Meyerhoff and Hatten (1968) believe that the geosyncline formed during Tithonian time; Khudoley (1967a, b) believes that it formed during Aptian time. The history of the Cuban part of this geosyncline—or island arc—is summarized by Furrazola *et al.* (1964, 1968), Khudoley (1967a, b), Kozary (1956, 1968), Meyerhoff (1967), Meyerhoff and Hatten (1968), and Wassall (1956). A volcanic belt (eugeosyncline) extended from western Cuba to the Virgin Islands. In Cuba, north of the volcanic belt, an intrageosynclinal welt separated the eugeosynclinal rocks on the south from the carbonate miogeosynclinal rocks on the north (Fig. 3). The miogeosyncline does not appear to extend east of Cuba.

During middle Cretaceous time (Albian through Turonian), Cuba was folded and large granodiorite batholiths were emplaced. Volcanic activity ceased in central and western Cuba, but continued in southern Oriente Province.

In latest Cretaceous time, orogenic activity again became very pronounced. Volcanic activity intensified in southern Oriente Province during Paleocene and early Eocene time. A general folding of Cuba took place, accompanied by large-scale faulting, and was followed by the intrusion of granodioritic batholiths or stocks in southern Oriente Province. Evidence for very large-scale thrusting and/or gravity thrusting has been published by Hatten (1967), Kozary (1956, 1968), Meyerhoff and Hatten (1968),[5] and Wassall (1956).

Major folding and faulting ceased in western and central Cuba by middle or early late Eocene time. Vertical movements continued in central and southern Oriente Province where the Bartlett Trough, south of Cuba, has been tectonically active since middle Cretaceous time. Except for local areas, post-middle Eocene strata in Cuba are flat lying or gently arched. Almost all tectonic activity since middle Eocene time has been related to vertical movements and strike-slip faulting.

Relation of Radiometric Dates to Cuban Geologic History

The radiometric dates shown on Table 1 comprise all of the published data of this type from Cuba.

Middle Cretaceous and older (?) thermal events.—The oldest definitely dated thermal event in Cuba was reported by Adamovich and Chejovich (1964, p. 14), who published a 120-m.y. date for a pegmatite dike cutting Jurassic(?) or older metamorphic rocks in northern Oriente Province (Fig. 1). This is locality 3 on Table 1 (119 m.y. ± 10 percent). Two dates not shown on the table—because their locations are uncertain—are 103 m.y. ± 2 percent and 121 m.y. ± 3 percent. They were run by Lamont-Doherty from specimens submitted by Hatten *et al.* (1958). Unfortunately, the exact locations of these two samples have not been verified, despite an intensive search, but we believe that both are from the Sancti Spiritus granodiorite near locality 2, Table 1. The two dates (103 and 121 m.y.), together with that reported by Adamovich and Chejovich (1964), suggest an Hauterivian to early Cenomanian (Harland *et al.,* 1964) thermal event, related possibly to the middle Cretaceous orogeny which affected all of Cuba.

However, locality 2 (Table 1; Fig. 1) from the Sancti Spiritus granodiorite is 180 m.y. ± 10 percent, latest Triassic or Early Jurassic. Khudoley doubts the validity of this date (Khudoley, 1967a, b). Hatten believes that the Sancti Spiritus granodiorite is a middle Cretaceous pluton (Hatten *et al.,* 1958). Meyerhoff (*in* Hatten *et al.,* 1958) once agreed with Hatten but now withholds judgment, because the Sancti Spriitus granodiorite is near, and even in contact with, the Jurassic(?) or Paleozoic(?) metamorphic rocks of the Trinidad Mountains (Fig. 1; *see* Furrazola *et al.,* 1964, 1968). The 180-m.y. figure conceivably is a "smeared" date —an older date that has undergone later thermal modification.

Summary of middle Cretaceous or older radiometric dates.—At least one locality (no. 3, Table 1; Fig. 1) records an Early to middle Cretaceous thermal event. Two additional dates not shown on Table 1, made by Lamont-Doherty (103 and 121 m.y.), also suggest that an Early to middle Cretaceous thermal event took place in Cuba. Until more dates are available, the problem remains unsolved, but it is almost certain that many of the plutons west of western Oriente Province are middle Cretaceous granodiorite, quartz diorite, and diorite batholiths and stocks (Hatten *et al.,* 1958, *summarized in* Furrazola *et al.,* 1964, 1968). Field observations in several areas of south-central Cuba by MacGillavry (1937, p. 18–20), Rutten (1936, p. 18–19), Thiadens (1937, p. 18–21), and van Wessem (1943, p. 13–16) support Hatten *et al.*'s (1958) conclusions.

Campanian-Maestrichtian through Eocene thermal events.—The last major orogeny to affect central and western Cuba began in Campanian time (about 76 m.y. ago) and ended during Eocene time. The onset of this event may be reflected in the dates from localities 4–6 (Table 1; Fig. 1); these dates range from 73 to 78 m.y. (Laverov *et al.,* 1967) and are from Jurassic(?) and Paleozoic(?) schists of the Isle of Pines. The dates could be "smeared" as a result of a later (Eocene?) thermal episode. The pre-Campanian age of the schists is proved by the fact that Albian-Cenomanian volcanic and pyroclastic rocks overlie the schist (Kuman and Gavilán, 1965).

The 61-m.y. date of locality 1 (Table 1; Fig. 1) is from the Tres Guanos quartz monzonite (Hatten *et al.,* 1958), a stock which intrudes an ancient metamorphic complex on the median welt (Figs. 1, 3). This date probably is not the true age of the Tres Guanos quartz monzonite, but more likely reflects the Campanian-Eocene orogeny which strongly folded most of Cuba. This opinion is supported by the fact that the rocks from which the date was obtained are overlain by Tithonian(?), Neocomian, and Aptian terrigenous clastic and lime-

[5] Khudoley (1967a, b) doubts that large-scale thrusting ever took place in Cuba.

Table 1. Radiometric Dates from Cuba

No. and Location	Rock Type	Stratigraphic Date	Method	Material Analyzed	Source	Age (m.y.)	Remarks
1. 700 m S12°W of Tres Guanos, Las Villas Province, at east end of Jarahueca fenster; in stream bed along road	Quartz monzonite	Pre-Neocomian	K-Ar[1]	Biotite	Lamont-Doherty Geol. Obs.	61 ± 3%	Paleocene. Tres Guanos quartz monzonite. Reported erroneously by Hatten and Meyerhoff (1968) as 67 m.y. and by Khudoley (1967b) as 57 m.y. Date is believed to be from secondary biotite formed during "Laramide" orogeny.[3] Hatten *et al.* (1958) believed that this is a late Paleozoic intrusion. Khudoley (1967a, b) believes that it is Late Jurassic. Area of outcrop is overlain by Neocomian-Aptian.
2. Near Manicaragua, southern Las Villas Province, north side of Sierra de Trinidad	Granodiorite	Pre-Campanian	K-Ar[2]	Whole rock	Laboratory of All-Union Geol. Inst., Leningrad: Khudoley (1967b)	180 ± 10%	Early Jurassic on Harland *et al.* (1964) scale. Khudoley is skeptical of validity of this date. Hatten *et al.* (1958) believed that this is a middle Cretaceous intrusive. Meyerhoff believes that it may be late Paleozoic. Khudoley believes that the date may be Late Jurassic, but more probably is middle Cretaceous.
3. 20 km south of Nicaro, northern Oriente Province	Pegmatite	—	K-Ar	Whole rock	Laboratory of All-Union Geol. Inst., Leningrad: Khudoley (1967b); Adamovich and Chejovich (1964)	119 ± 10%	Hauterivian (Early Cretaceous). Pegmatite dike cuts metamorphic rocks of Jurassic(?) age according to Adamovich and Chejovich (1964).
4. Isle of Pines, Habana Province	Muscovite schist	Pre-Albian	K-Ar	Muscovite	Laboratory of All-Union Geol. Inst., Leningrad: Khudoley (1967b)	76 ± 2	Senonian (Late Cretaceous). Kuman and Gavilán (1965) erroneously reported 190-m.y. date (Khudoley, 1967a, p. 673, footnote 4; 1967b, p. 789, footnote 7). Dates from Isle of Pines probably reflect "Laramide" events.
5. Isle of Pines, Habana Province	Muscovite schist	Pre-Albian	K-Ar	Muscovite	Laboratory of USSR Acad. Sci., Moscow: Laverov *et al.* (1967)	78 ± 4	Senonian. Early event of "Laramide" orogeny?
6. Isle of Pines, Habana Province	Muscovite schist	Pre-Albian	K-Ar	Muscovite	Laboratory of USSR Acad. Sci., Moscow: Laverov *et al.* (1967)	73 ± 4	Senonian. Early event of "Laramide" orogeny?
7. Daiquirí area, 20 km east of Santiago de Cuba, southern Oriente Province	Quartz diorite	Pre-Oligocene	K-Ar	Whole rock	Laboratory of USSR Acad. Sci., Moscow: Laverov *et al.* (1967)	49 ± 6	Early-middle Eocene. Sierra Maestra. Late in "Laramide" orogeny.
8. Nima-Nima area, 20 km west of Santiago de Cuba, southern Oriente Province	Plagiogranite porphyry	Pre-Oligocene	K-Ar	Whole rock	Laboratory of USSR Acad. Sci., Moscow: Laverov *et al.* (1967)	46 ± 6	Early-middle Eocene. Sierra Maestra. Late in "Laramide" orogeny.
9. Nima-Nima area, 20 km west of Santiago de Cuba, southern Oriente Province	Diorite	Pre-Oligocene	K-Ar	Whole rock	Laboratory of USSR Acad. Sci., Moscow: Laverov *et al.* (1967)	58 ± 8	Paleocene. Sierra Maestra. Late in "Laramide" orogeny.

[1] Decay constants used from Lamont-Doherty are:
$\lambda_\epsilon = 0.584 \cdot 10^{-10} yr^{-1}$; $\lambda_\beta = 4.72 \cdot 10^{-10} yr^{-1}$; $\lambda_\epsilon / \lambda_\epsilon + \lambda_\beta = 0.11$; $K^{40}/K = 0.000119$ atomic percent.

[2] All USSR measurements used following decay constants:
$\lambda_\epsilon = 0.557 \cdot 10^{-10} yr^{-1}$; $\lambda_\beta = 4.72 \cdot 10^{-10} yr^{-1}$; $\lambda_\epsilon / \lambda_\epsilon + \lambda_\beta = 0.11$; $K^{40}/K = 0.0122$ percent (weight).

[3] "Laramide" is used only in the sense of Late Cretaceous-Eocene orogeny. Equivalence with type area of Laramide orogeny is not intended.

stone strata, and by spilitic volcanic rocks interbedded with the Tithonian(?), Neocomian, and Aptian. Khudoley (1967a, b) regards the Tres Guanos as a Late Jurassic intrusion; Meyerhoff and Hatten (1968) believe the Tres Guanos to be Paleozoic.

Localities 7–9 (Table 1; Fig. 1) are in the Sierra Maestra west and east of Santiago de Cuba, along the south coast of Oriente Province. The 46–58 m.y. dates show that quartz dioritic rocks intruded this region during late Paleocene and middle or late Eocene times. Southern Oriente Province is the only area in Cuba where batholithic intrusions of these ages are known. The occurrence of these young batholiths in southern Oriente corroborates our interpretation of the geologic history of Cuba; specifically, after middle Cretaceous time, volcanic activity (eugeosynclinal development) ceased in western and central Cuba, but continued in southern Oriente Province.

Summary of Campanian-Eocene radiometric dates.—The terminal folding phase in Cuba that began in Campanian-Maestrichtian time affected the entire island. However, eugeosynclinal conditions continued in southern Oriente Province. These conclusions are corroborated by the 61–78 m.y. dates in pre-Albian to pre-Neocomian rocks of western (Isle of Pines) and central (loc. 1, Table 1) Cuba, and by the 46–58 m.y. dates in undeformed quartz dioritic batholiths in southern Oriente Province.

Erroneous dates in published literature.—Kuman and Gavilán (1965, p. 24) published a 190-m.y. date for the Isle of Pines schists. Khudoley (1967a, p. 673, footnote 5; 1967b, p. 789, footnote 7) reported that the 190-m.y. date was an error for which he was responsible, and that the date should have been 74–78 m.y. (loc. 4, Fig. 1, Table 1). Meyerhoff and Hatten (1968, p. 320, footnote 4), because of a misunderstanding of a letter from Khudoley, reported the "corrected" date for the Isle of Pines as 180 m.y. Actually, the 180-m.y. date is from the Sancti Spiritus granodiorite in southern Las Villas Province, central Cuba (loc. 2, Fig. 1, Table 1).

Meyerhoff (1967, p. 218) reported the 180-m.y. date as Late Triassic, whereas the Harland *et al.* (1964) scale shows this date to be Early Jurassic. Khudoley (1967b, p. 789), using a 1958 memorandum in Cuban government files (Lamont-Doherty report), assigned a 57-m.y. date for the Tres Guanos quartz monzonite, central Las Villas Province. The date to this was given incorrectly as 67 m.y. (loc. 1, Fig. 1, Table 1) by Meyerhoff and Hatten (1968, p. 320); this error was caused by a typing mistake in the unpublished Hatten *et al.* (1958) report. Hatten (1967, p. 781), using information supplied by Meyerhoff, reported late Paleozoic radiogenic dates for the metamorphic rocks of the Isle of Pines and the Sierra de Trinidad. This information was given orally to Meyerhoff in July 1966 by Sara Ysalgué de Massip of the Cuban Academy of Sciences, but Dr. Ysalgué's statement since has proved to be the result of a misunderstanding of the geochronologic time scale.

Summary of Interpretation of Radiometric Dates

1. The 103-m.y. and earlier radiometric dates indicate that one or more thermal events—including the intrusion of batholiths and stocks in central and western Cuba—took place in Cuba during and before Cenomanian (middle Cretaceous) time. It is not yet possible to establish the cause (or causes) of the range in dates from 103 to 180 m.y. They could reflect two thermal episodes, "smearing" of an older event (or events), or some other cause.
2. The 61–78-m.y. dates from central Cuba are from pre-Albian or pre-Neocomian rocks. These ages reflect the beginning of the Late Cretaceous–middle Eocene orogeny, and the earliest dates could indicate "memory" of older events.
3. The 46–58-m.y. quartz diorite intrusive rocks of southern Oriente Province support the field interpretation of that area—specifically, that southern Oriente Province continued to be an actively sinking eugeosynclinal basin long after volcanic activity ceased to be important west of Oriente Province.

Conclusions

The radiometric dates, in Khudoley's (1967a, b) opinion, reflect intrusive and orogenic events related to Late Jurassic, middle Cretaceous, and Campanian-Eocene orogenic episodes. Hatten and Meyerhoff (1968), in contrast, believe that, whereas the later dates reflect middle Cretaceous and Campanian-Eocene thermal events, certain dates *could* be altered from a Paleozoic event. Only considerable additional sampling and dating will resolve this fundamental controversy in Cuban geology. Some of the results obtained corroborate field mapping, but other results are conflicting. Clearly, much work remains to be done.

We believe that it is important to note that, with the exception of the 180-m.y. date (loc. 2, Table 1), the results of radiometric determinations are similar to those obtained in the other islands of the Greater Antilles geosyncline (Khudoley and Meyerhoff, 1968). From this fact we conclude that the radiometric method is proving to be a useful tool in corroborating the long-held opinion that the entire Greater Antilles geosyncline has had a similar and genetically related history of geologic development.

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