A triassic time scale dilemma : K-Ar dating of Upper Triassic mafic igneous rocks, Eastern U.S.A. and Canada and Post-Upper Triassic plutons, Western Idaho, U.S.A.

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Objekttyp: **Article**

Zeitschrift: **Eclogae Geologicae Helvetiae**

Band (Jahr): **63 (1970)**

Heft 1: **Geochronology of phanerozoic orogenic belts : papers presented at the "Colloquium on the Geochronology of Phanerozoic Orogenic Belts"**

PDF erstellt am: **25.09.2024**

Persistenter Link: https://doi.org/10.5169/seals-163810

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Eclogae geol. Helv.	Vol. 63/1	Pages 15–28	With 4 figures in the text and 3 tables	Basle, April 1970

A Triassic Time Scale Dilemma: K-Ar Dating of Upper Triassic Mafic Igneous Rocks, Eastern U.S.A. and Canada and Post-Upper Triassic Plutons, Western Idaho, U.S.A.

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ABSTRACT

K-Ar dates for Newark Group (Upper Triassic) dolerite dikes and sills and basalt flows cluster about 200 m.y. with a scatter toward lower values. Dates for several dolerite dikes in Connecticut, Pennsylvania, Virginia, and North Carolina are in the range 220 to 244 m.y. with a concentration about 225–230 m.y. Intrusive igneous rocks in western Idaho that cross-cut marine Upper Triassic strata have been dated as approximately 206 m.y. old. Both groups of data conflict with currently accepted estimates of the age of the Triassic-Jurassic boundary.

Zeolite facies "burial" metamorphism of the Newark Group sediments and volcanics has occurred and may explain the cluster of dates around 200 m.y. No unique solution to the problem can be obtained from this data but an explanation consistent with published dates relating to Triassic and Jurassic time proposes a boundary between the periods at approximately 210 m.y., invoking Ar loss during metamorphism to explain low dates and the possibility of extraneous Ar to explain dates above 227 m.y. obtained for two dikes with exceptionally low K content (< 0.1 %).

Introduction

The geologic studies reviewed by SANDERS (1963) and paleomagnetic work of DEBOER (1967, 1968) led to the conclusion that the mafic intrusive and extrusive igneous rocks related to the Upper Triassic Newark Group sediments of eastern North America (Fig. 1) were the product of more than one episode of igneous activity. DEBOER (1968) recognized significant differences in the orientation of remanent magnetism for each of the three composite lava flows in Connecticut-Massachusetts and for steeply dipping dikes that were younger than most of the deformation of the sediments and interbedded lavas (SANDERS, 1963). In his first paper, DEBOER proposed that the basaltic dikes of the Appalachians were Jurassic in age because their magnetism was intermediate between that known for Triassic and Cretaceous rocks from other North American localities. An alternate explanation of the data that could not be excluded was that the geomagnetic field fluctuated rapidly during Late Triassic time and although the correlations between units were correct the time intervals involved were short.

We set out to test these ideas by K-Ar dating of a number of samples from the Upper Triassic volcanic rocks and from several of the dike swarms studied by DEBOER. Several analysed specimens were exactly those used for the paleomagnetic work. Our own collecting was concentrated in southern Connecticut (Fig. 2). Our

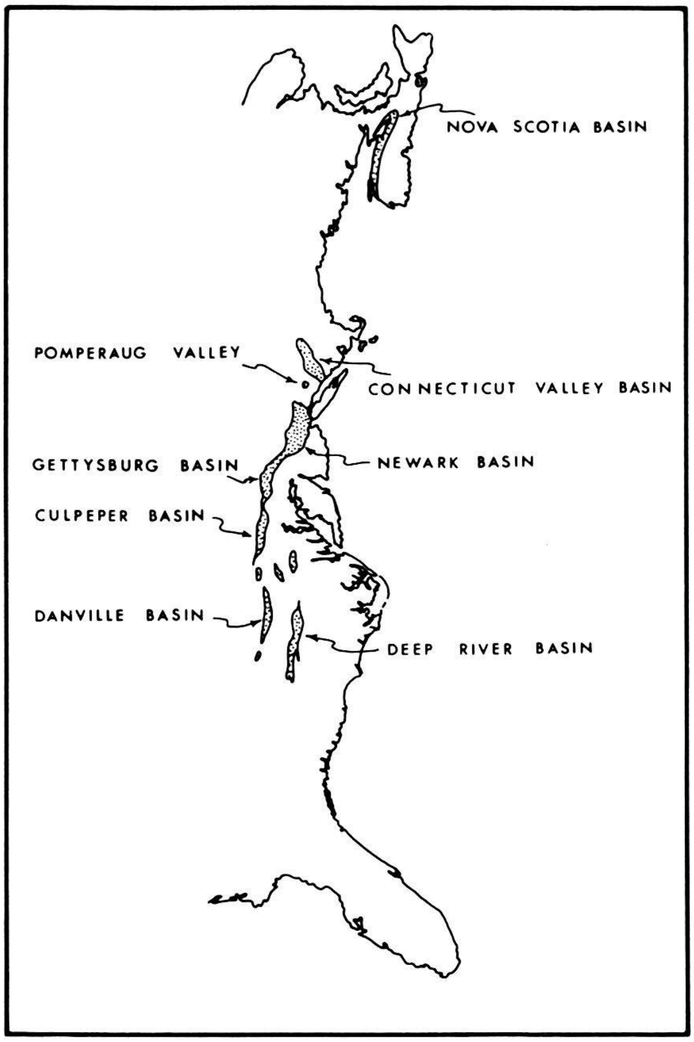

Fig. 1.
Map showing the distribution of Upper Triassic sediments in eastern North America (SANDERS, 1963).

K-Ar data were unable to resolve the original question of difference in age of the dikes and volcanic rocks. In fact, several dikes gave dates older than the volcanic rocks and much of the data was inconsistent with the Triassic time scale indicated by recent work, including results obtained by us for granitic plutons in western Idaho that cross-cut rocks at least as young, and probably younger than the Newark Group. The problem then became the one discussed in this paper.

Age of Upper Triassic rocks – review

The Palisades sill, an Upper Triassic intrusive into Newark Group sediments has been a traditional point of calibration of time scales since the early attempts of HOLMES (1937). The definitive work was that of ERICKSON and KULP (1961) who obtained a date of 190 ± 5 m.y. for a biotite separate from the sill and considered it to give the best estimate of its age. The work of FANALE and KULP (1962) on the Palisades biotite and Upper Triassic iron deposits near Cornwall, Pennsylvania, revised this

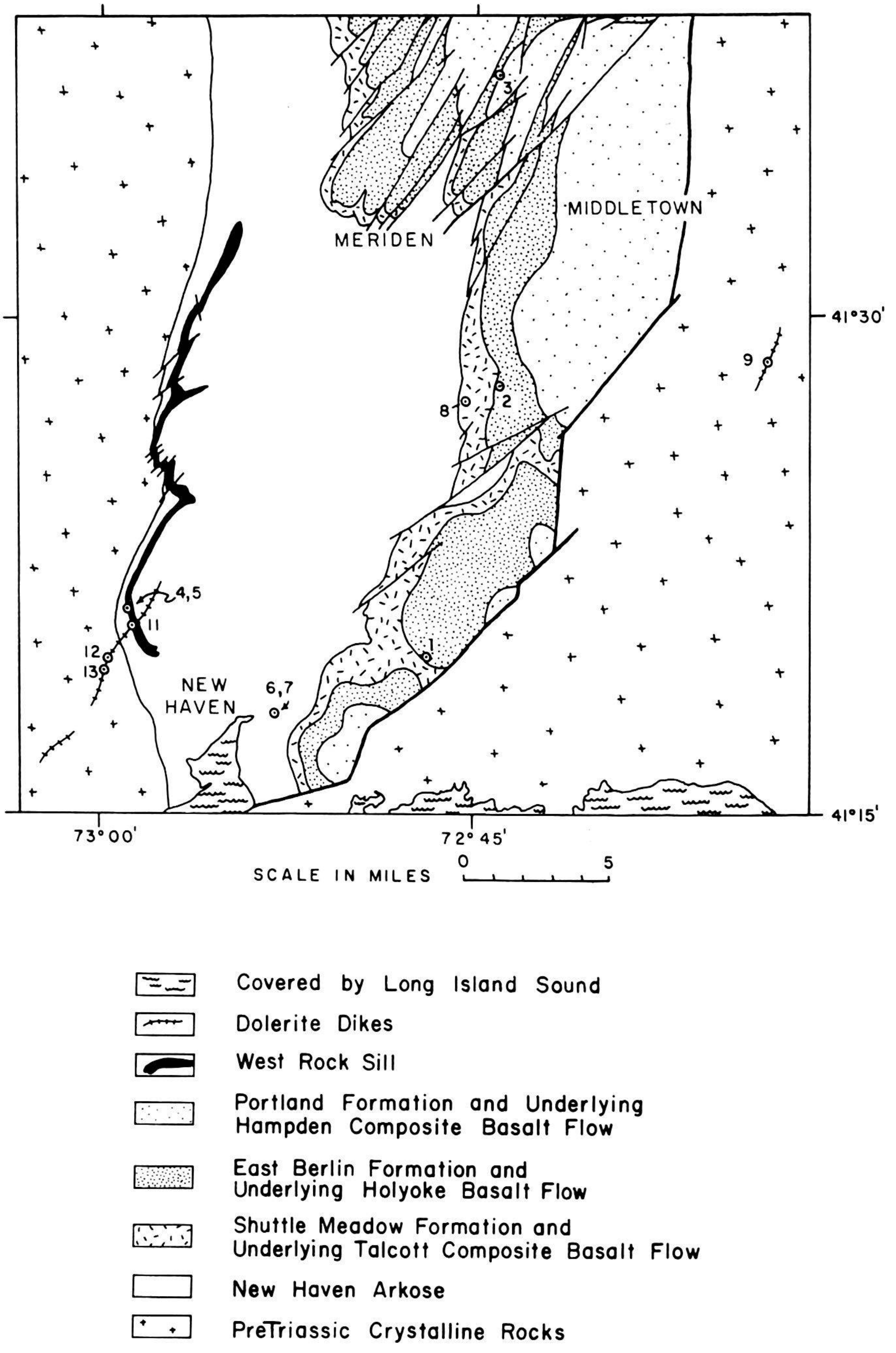

Fig. 2. Geologic map of central southern Connecticut showing sample localities and generalized distribution of rock units. Modified from sources listed by SANDERS (1963).

value to 196 m.y. A date of 197 m.y. was obtained for a mafic dike in Nova Scotia by LAROCHELLE and WANLESS (1966). CHARMICHAEL and PALMER (1968) reported an age of 200 m.y. for Upper Triassic North Mountain Basalt, Nova Scotia, but their data included a wide range of numbers, 178–217 m.y., excluding one sample which gave 328 m.y., all K-Ar on whole-rock basalt. Dates of 193 and 191 m.y. for Upper Triassic lavas in New England were reported by DEBOER (1968). All this work consistently indicated an age of about 195 m.y. for Upper Triassic Newark Group volcanic rocks.

The Guichon batholith in western Canada was originally considered to mark the Triassic-Jurassic boundary at 180 m.y. (BAADSGAARD et al., 1961) but it is only known to be post-Karnian, perhaps even post-Norian in stratigraphic age and it has recently been accurately dated as 200 ± 5 m.y. (WHITE et al., 1967). The tin granites of Indonesia, of earliest Jurassic age, gave K-Ar dates of 180 m.y. but are now known to be older, yielding Rb-Sr dates of 201–205 m.y. and U-Pb, Th-Pb dates from 195 m.y. (zircon) to approximately 220 m.y. (monazite) (EDWARDS and MCLAUGHLIN, 1965).

The maximum ages of Upper Triassic uranium ores dated by MILLER and KULP (1963) were in the range 200–220 m.y. in stratigraphic units approximately correlative with the Newark Group. WEBB and MCDOUGALL (1967) proposed a minimum age of 215–220 m.y. for Middle Triassic sediments, consistent with MILLER and KULP's data.

The recent review by TOZER placed the Triassic-Jurassic boundary about 190–200 m.y. ago (TOZER, 1964), a value long advocated by some Russians (RUBINSHTEYN, 1961). Even more recent work done by BORSI and FERRARA (1967) has established an unusually precise date of 230 m.y. for the Middle-Upper Triassic boundary in northern Italy. BOCHKAREV and POGORELOV (1967) using entirely independent data have proposed a Triassic Period beginning 255–260 m.y. ago and ending 204 m.y. ago, consistent with HOLMES' (1959) estimate of a 50 m.y. duration for the Triassic based on relative thickness of Triassic sediments in the geologic column.

It should already be apparent that the Palisades date is inconsistent with other Triassic time-scale dates and that, in general, the age for the boundaries of the Triassic have been growing older as more precise information becomes available.

Analytical methods

Atomic absorption spectrophotometric techniques were used for K analysis and conventional isotope dilution techniques for Ar analysis. The material analysed for Ar was mostly 2 to 5 mm grains of whole rock, crushed and sieved, but otherwise untreated. Part of each sample was ground to < 100 mesh for K analysis. Analytical precision, derived from the mean range of the duplicate analysis made during this study is 3% for K, 4% for Ar, yielding a 6% uncertainty (σ) for the K-Ar dates. This is not as good as the precision ($\sigma \leqq 2\%$) attainable with fine grained, pure mineral separates containing several percent K analysed under exactly the same conditions. Analysis of standard minerals indicates that calibrations are accurate within 2%. All dates are calculated using the constants: $K\lambda_\beta = 4.72 \times 10^{-10}\,\text{yr}^{-1}$, $K\lambda_e = 0.584 \times 10^{-10}\,\text{yr}^{-1}$, $K^{40}/K = 0.0119$ atom percent. Sample descriptions, analytical data and K-Ar dates are given in Tables 2 and 3.

Dating mafic volcanic-hypabyssal rocks

Detailed dating studies using pre-Tertiary whole-rock basalt and dolerite specimens have been made by Erickson and Kulp (1961), McDougall (1961), Payne and others (1965) and Fitch and Miller (1967), among others, and limited optimism for the method appears justified. In spite of collection of unweathered samples and precautions taken to discard samples with evident alteration it is usual to obtain a spectrum of discordant dates and to select the concentration of highest values as the correct "age". In the case of dikes the chilled margins usually give higher dates than more coarsely crystalline interior portions; results for lavas are less systematic. Excess Ar has been observed in mafic dikes by Evans and Tarney (1964) and in recent submarine lavas (Dalrymple and Moore, 1968; Funkhouser et al., 1968) and cannot be excluded as an explanation of some high dates. Except for one odd felsite dike all of the samples dated in the present study were completely unweathered and all appeared free of alteration in hand specimen but under the microscope none of them could be considered 100% unaltered when compared with Pliocene to Recent Basalts. Nevertheless, a casual examination would tend to ignore the minor amounts of alteration present in many of the samples, considering it deuteric or volumetrically insignificant. Fresher samples simply cannot be found in the area studied.

West Rock Sill compared with Palisades Sill and lava flows

The Palisades biotite sample (supplied by G. Erickson) when analysed at Yale gives a result within 1% of the Lamont date indicating that no significant bias affects comparisons of the results of the two laboratories. The West Rock Sill in Connecticut is geologically similar but somewhat smaller than the Palisades Sill dated by Erickson and Kulp (Fritts, 1963; Walton and O'Sullivan, 1950). Both sills show a similar pattern of discordance – the highest dates at the margins, lower values inside (Table 1). The amount of discordance is much greater in the Palisades samples but the highest dates on both sills are in excellent agreement at 201–202 m.y. This would seem a tempting argument for an interpretation of an absolute age of between 193 and 202 m.y. for both sills. Further support of this is provided by a date of 195 m.y. for biotite from tuffaceous sandstone underlying the North Mountain Basalt in Nova Scotia. The sediments containing the biotite are reported to be middle Upper Triassic by Klein (1962).

Table 1. Comparison of K-Ar dates for West Rock Sill, Connecticut and Palisades Sill, New York and New Jersey.

	K-Ar Date Yale	K-Ar Date Lamont (5, 6)		K-Ar Date Yale West Rock	K-Ar Date Lamont (5, 6) Palisades
Palisades Biotite	192	190, 196	Fine Grained		202
	West Rock	Palisades	Medium Grained	190	166, 142
Chilled Margin	201	202	Coarse Grained	198	162

Table 2. Sample descriptions, analytical data, and K-Ar dates: Localities in Connecticut (see figure 2).

	Sample		Selected descriptive information	% K	Radiogenic Ar^{40} STP cc × 10^6 Percent Air correction in Parentheses	Date m.y.
1.	Holyoke Basalt Quarry, S end of Totoket Mtn.	A	Basalt 18% patchy alteration to chlorite, sericite, zeolite, pumpellyte, calcite, clay, etc.	0.78, 0.77	6.55 (29)	201 ± 12
		B	Basalt 10% clay, calcite, pumpellyte in alteration products. Quartz, calcite in voids.	0.82, 0.79	5.38 (12)	161 ± 9
		C	Basalt 20% alteration to chlorite, sericite, celadonite, pumpellyte, calcite.	0.68, 0.70	5.77 (38)	197 ± 12
2.	Holyoke Basalt, Pegmatitic Zone, Reeds Gap Quarry, East Wallingford		Pegmatite-elongate laths of plagioclase and pyroxene up to 1 cm long. Interstitial quartz and alteration products-chlorite, pumpellyte, zeolites, clays, etc.	0.44, 0.46	3.33 (68)	176 ± 11
3.	Hornfels below Hampden Basalt, Township of Berlin along Conn. 72. Section described by CHAPMAN, 1965.		Arkosic sandstone with calcite cement. 4% chlorite and phengite, celadonite present.	0.89, 0.90	7.32 (39)	195 ± 12
4.	West Rock Sill, Quarry, E of Konolds Pond.	A	Chilled base-Dolerite (0.5 mm long plagioclase) 8% chlorite, actinolite, sericite.	0.37, 0.35, 0.37, 0.36	3.07 (27), 3.09 (33), 3.21 (38), 2.92 (46)	201 ± 6
		B	Dolerite (2–3 mm long plagioclase) more micropegmatite and quartz than other West Rock samples 12% chlorite, sericite, trace of actinolite.	0.49, 0.47	4.00 (40)	198 ± 12
5.	West Rock Sill, Baldwin Parkway, above Quarry.		Dolerite (1–2 mm long plagioclase) 2–3% chlorite.	0.36, 0.37	2.93 (46)	190 ± 12
6.	Basalt Dike, Railroad cut, Fair Haven.		Basalt 12% devitrified glass 2–3% chlorite.	0.43, 0.42	3.55 (53)	198 ± 12
7.	Felsite Dike, Railroad cut, Fair Haven described by HOVEY, 1897.		"Keratophyre" Sericitized albite and K-feldspar in a cloudy matrix with chlorite, clay, celadonite (?), hematite	1.72, 1.75	13.08 (8)	180 ± 10
8.	Camptonite Dike near East Wallingford described by RUSSELL, 1922.		Euhedral augite, brown amphibole, and opaques in a glassy matrix.	2.13, 2.14	13.45 (33)	151 ± 9
9.[a]	Higganum Dike, New Routes 9 and 81. Collected by J. DE BOER.	A	Dolerite 6% clay, chlorite.	0.40, 0.40	3.23 (58)	192 ± 12
		B	Dolerite 6% clay, chlorite.	0.41, 0.39	3.26 (60)	194 ± 12
10.[a]	Buttress Dike, Wilbur Cross Parkway. Collected by J. DE BOER.	A	Dolerite 3% chlorite, clay.	0.35, 0.37	3.50 (57), 3.28 (48)	223 ± 10
		B	Dolerite 6% chlorite, clay.	0.35, 0.35	3.34 (69)	226 ± 13
11.	Buttress Dike, West Rock.		Dolerite 5% chlorite, clay (1 mm long plagioclase, 1–2 mm subophitic pyroxene).	0.29, 0.29	2.39 (37)	197 ± 12
12.	Buttress Dike, N. side of Bishops Pond.		Dolerite 5% chlorite, clay (1 mm long plagioclase, 1–2 mm ophitic pyroxene).	0.39, 0.41	3.46 (32)	206 ± 12
13.	Buttress Dike, Wilbur Cross Parkway.		Dolerite 2–3% chlorite (1–2 mm long plagioclase, 2–3 mm ophitic pyroxene).	0.37, 0.36	3.42 (34), 3.16 (42)	214 ± 9
14.	Basalt, Rattlesnake Hill, Pomperang Valley. Collected by D.F. SCHUTZ.		Dolerite 6% pale brown glass, very fresh looking.	0.23, 0.21	1.46 (83), 1.54 (81)	164 ± 10

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[a] Samples studied paleomagnetically by J. DEBOER.

Table 3. Sample descriptions, analytical data, and K-Ar dates: Appalachian Localties and Western Idaho.

	Sample	*N. Latitude*	*W. Longitude*	*Material Analysed*	*% K*	*Radiogenic Ar^{40} STP cc × 10^6 Percent Air Correction in Parentheses*	*Date m.y*
	Nova Scotia						
15.	Biotite bearing ash bed in Blomidon Formation 0.25 mi. N. of Central Clarence, Anapolis County. Collected by G. deVries Klein.	44° 54.5′	65° 13′	Biotite (8% Chlorite)	5.31, 5.41	44.52 (15)	195 ± 4
	New Jersey						
16.	Palisades Sill. Mineral separate supplied by G. Erickson			Biotite (no Chlorite)	6.82, 6.81 6.72, 6.86	54.5 (8), 54.9 (19) 55.4 (5)	192 ± 2
	Pennsylvania						
17.a)	Dike 3 mi. SE Pottstown, Montgomery County. Gettsburg Basin. Dike crosscuts Brunswick Formation. Collected by J. deBoer.	40° 14′	75° 32′	Whole Rock (1% Clay, Chlorite)	0.40, 0.38	3.75 (41), 3.76 (46)	227 ± 10
				Whole Rock (1% Clay, Chlorite)	0.41, 0.41	3.86 (30)	223 ± 13
	Virginia						
18.a)	Dike, Bingham Mountain, Greene County. Crosscuts Paleozoic Crystalline Rocks. Collected by J. deBoer.	38° 15′	78° 32′	Whole Rock (2% Clay)	0.099, 0.099	1.01 (82), 0.98 (84)	236 ± 14
	North Carolina						
19.a)	Dike, 0.3 mi. SW of Lebanon Church, Deep River Basin. Collected by J. deBoer.	35° 32′	79° 05′	Whole Rock (1% Clay, Chlorite)	0.091, 0.093	0.97 (82)	244 ± 15
	Western Idaho						
	YAG-979 Hornblende Biotite Granodiorite Cuddy Mountain district. Collected by C. W. Field.	44° 43.3′	116° 48.25′	Biotite (40% Chlorite, 4% Quartz, Feldspar)	2.46, 2.45	19.18 (13), 18.35 (15), 18.23 (15)	181 ± 4
				Hornblende (18% Chlorite, 2% Quartz, Feldspar)	0.258, 0.257	2.17 (44), 2.19 (45)	201 ± 8
	YAG-984 Biotite Hornblende Quartz Diorite Cuddy Mountain district. Youngest and freshest pluton in complex. Collected by C. W. Field. A biotite K-Ar date of 216 ± 5 m.y. was determined for this pluton by Isotopes Inc. (C. W. Field, personal communication, 1967).	44° 47.75	116° 44.30′	Biotite (35% Chlorite, 10% Hornblende)	2.93, 2.94	24.60 (26)	200 ± 4
				Hornblende (3% Chlorite, 1% Biotite)	0.366, 0.373	3.52 (37), 3.46 (39)	217 ± 8
					0.388, 0.393		

a) Samples studied paleomagnetically by J. deBoer.

The dates for lava flows and a sub-flow hornfels in southern Connecticut also fall within this cluster around 200 m.y. although a few samples are discordantly lower (201, 197, 195, 176, and 161 m.y.). If the maximum values are considered correct the results might be considered confirmation of the stratigraphic and paleomagnetic observations correlating the sills and lava flows.

Discordant results for dikes

Analysis of drill core samples from the paleomagnetically studied dikes gave dates that were either similar to the above-mentioned concentration of dates around 200 m.y., or greater, up to approximately 240 m.y. Repeated analysis confirm that the discrepancies are real and not the result of analytical uncertainty. Except for two dikes very low in K (less than 0.1 %) the anomalous results cluster around 225 m.y., seemingly older than the volcanic rocks and sills that they crosscut (the field evidence for this is indisputable). The anomaly exists for samples from localities in North Carolina, Virginia, Pennsylvania, and Connecticut. As a group, the dike dates are distinctly different (> 90 % confidence level) from the 198 m.y. mode of the sills and lava flows.

The Buttress Dike, which crosscuts the West Rock Sill, was studied in greater detail than were the other dikes. The original drill core samples dated 223 and 226 m.y. An additional sample from nearly the same locality, collected at a later date, gave 214 m.y. A sample of the dike where it cuts West Rock gave 197 m.y., a value very close to the West Rock dates and a sample at an intermediate locality gave an intermediate date, 206 m.y. Two possible explanations are available, and they are not mutually exclusive. Either the dikes contain extraneous Ar or there is a pattern of discordance in which alteration has produced a cluster of dates around 200 m.y. and only the older dates around 225–230 m.y. are meaningful age determinations.

Regional "burial" metamorphism of Newark Group sediments and volcanic rocks

Careful petrographic examination of Newark Group sediments and volcanics in New Jersey, Connecticut, and Nova Scotia confirms that they have been metamorphosed. The occurrence of prehnite and other zeolites in the lava flows in New Jersey has been a stimulus to mineral collectors for nearly a century. VAN HOUTEN (1962) has described the analcime-rich sediments in New Jersey and observed conversion of analcime to albite with increasing depth of burial. HEALD (1956) observed laumontite in Triassic arkoses in Connecticut and his observation has been abundantly confirmed by S. BACHINSKI and D. COOMBS (personal communication). J. SUPPE collected massive pumpellyite from a breccia cutting the Holyoke lava flow in Connecticut and subsequently we have discovered it in thin sections of some of the material dated. Metamorphic epidote was identified by BACHINSKI and COOMBS in an arkose sample and in one dated specimen from the West Rock Sill actinolite appeared to be a product of the incipient metamorphism of the dolerite although the original igneous character of the rock is still largely preserved intact. Poorly characterized "chlorite" and clays may be observed petrographically and on X-ray diffractometer traces of virtually all of the specimens dated. AUMENTO and FRIEDLANDER (1966) have described some of the assemblages of zeolites that occur in the Triassic basalts of Nova Scotia.

The petrographic work is limited in extent but it is clear that metamorphism of the rocks has occurred either in the zeolite or the prehnite-pumpellyite facies of regional metamorphism described by COOMBS (1960, 1961). This means that the rocks have been cooked at temperatures on the order of 200 °C at some time subsequent to deposition, making some loss of Ar not only possible, but likely. According to DAMON (1968), 50 m.y. at a temperature as low as 100 °C can lead to a 10% Ar loss from biotite. HART and others (1968) considered biotite K-Ar dates to be potentially one of the most sensitive indicators available for detecting incipient metamorphism. Thus in spite of the consistent grouping of biotite and whole-rock dates around 200 m.y. there is no reason to accept this as an age for the igneous rocks as all of the samples are suspect, the dikes as well as the lava flows. If the dikes give the correct age it is only by the accident of their lesser alteration, not due to inherent differences between them and the sills and flows.

Post-Upper Triassic plutons, Western Idaho

FIELD and others (in press) have mapped several granitic plutons in the vicinity of Cuddy Mountain, Idaho. These igneous rocks crosscut greenschist metamorphosed Upper Triassic sedimentary and volcanic rocks (HAMILTON, 1963). K-Ar dates for two plutons of this group, analysed at the same time as the other Triassic time-scale samples and thus exactly comporable, range from 181 and 200 m.y. for biotite to 201 and 217 m.y. for hornblende separates. A best choice of minimum age would be about 206 ± 6 m.y. (mean of the three highest dates), rather similar to the Guichon Batholith results cited earlier. This igneous complex whose age is near the Triassic-Jurassic boundary has few counterparts within the Cordillera of the western U.S. but several are known to occur in western Canada (WHITE, 1968). Triassic K-Ar dates have been reported for two localities in California by MCKEE and NASH (1967) and EVANS (1966), but in those cases the stratigraphic relationships are less restrictive and the rocks may be Upper Triassic, or even older.

It does not seem possible to accept both this result and the Palisades dates as age determinations as they are in stratigraphic conflict, the geologically younger plutons in Canada and Idaho giving older dates than the Upper Triassic Palisades Sill and related lava flows.

Interpretation

A unique solution for the age of the Upper Triassic Newark Group is not achieveable using the data available and it is doubtful that additional work on Newark Group rocks will resolve the problem as all results are suspect, either of Ar loss due to metamorphism, or of excess Ar. There is no way of knowing *a priori* when these contrary effects cancel out so that identification of the ideal sample becomes an exercise in frustration.

A possible consistent, but certainly not unique, interpretation for the geologic time scale is illustrated in Figures 3 and 4 which summarize the relevant data. If dates of 200 and 206 m.y. are considered post-Triassic and 230 m.y. the Middle-Upper

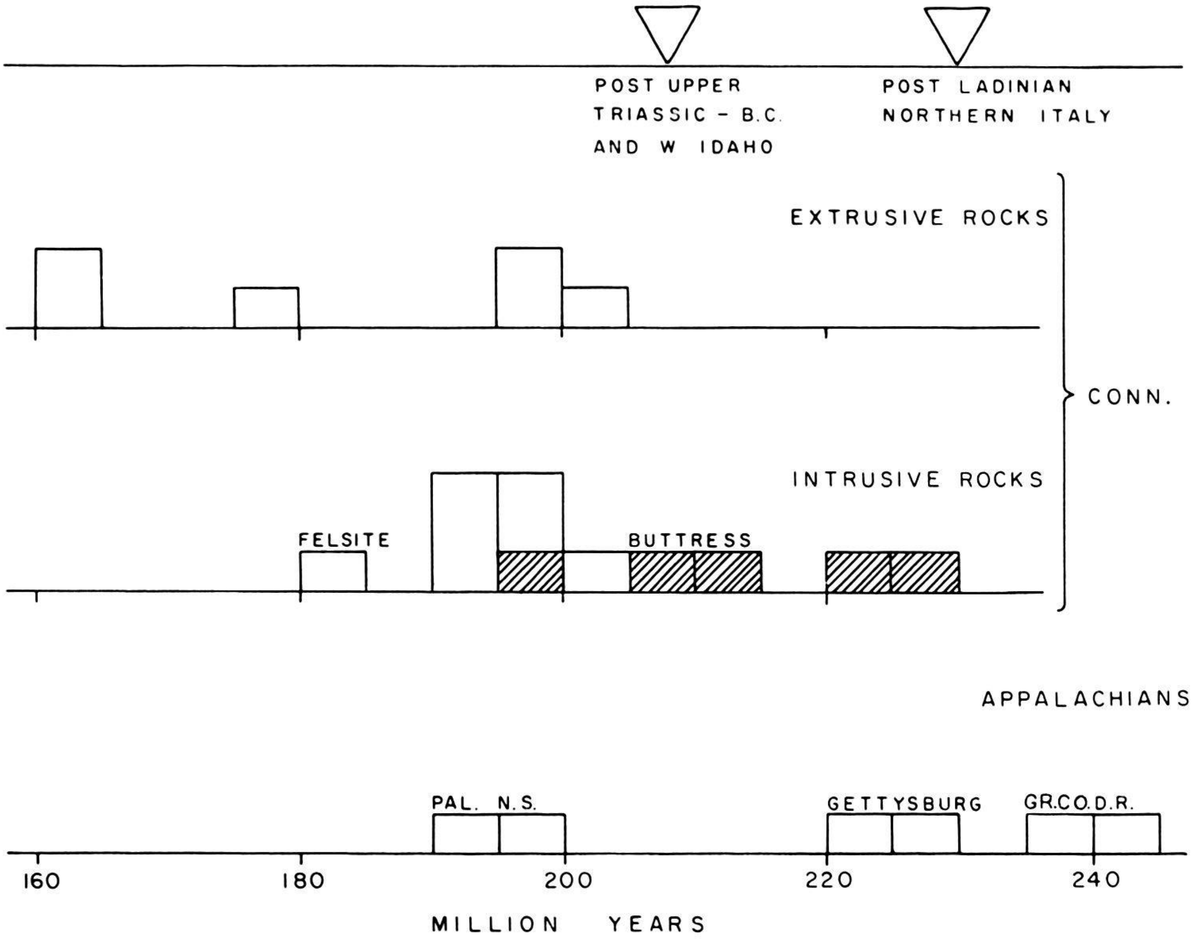

Fig. 3. Histogram summarizing K-Ar dates for Newark Group lavas and dolerite dikes and sills as well as time scale calibration points for pre and post Upper Triassic rocks in Italy and North America, respectively (Borsi and Ferrara, 1967; White et al., 1967). The Buttress dolerite dike samples are shaded.

Triassic boundary, then 210 m.y. may be taken as the value of the Triassic-Jurassic boundary. This would make the older dates for the Buttress and Gettysburg dikes ~225 m.y. a fortuitously correct date for the Newark Group. The somewhat older dates for low K ($<0.1\%$) dikes in the southern Appalachians are not, with statistical confidence, separable from the 225 m.y. group because of fairly large analytical uncertainties. If included they raise the average to 230 m.y. but it is also possible, although not provable, that they contain extraneous Ar; their status must remain doubtful. The cluster of dates around 200 m.y. may have more to do with the low-grade metamorphism of the rocks, than with anything else. The dates would suggest that the metamorphism occurred at about the end of the Triassic. The scatter of dates below 200 m.y. must be due to poor Ar retentivity of the samples as a consequence of alteration or may represent the effects of alteration after the beginning of the Jurassic.

A figure of about 255 m.y. was used for the base of the Triassic in Figure 4 but it is rather arbitrary and can only be defended as "reasonable". It is not based on accurate age determinations but does fit comfortably into the time scale based on cumulative maximum sediment thickness (Holmes, 1959) and is not in irreconcilable

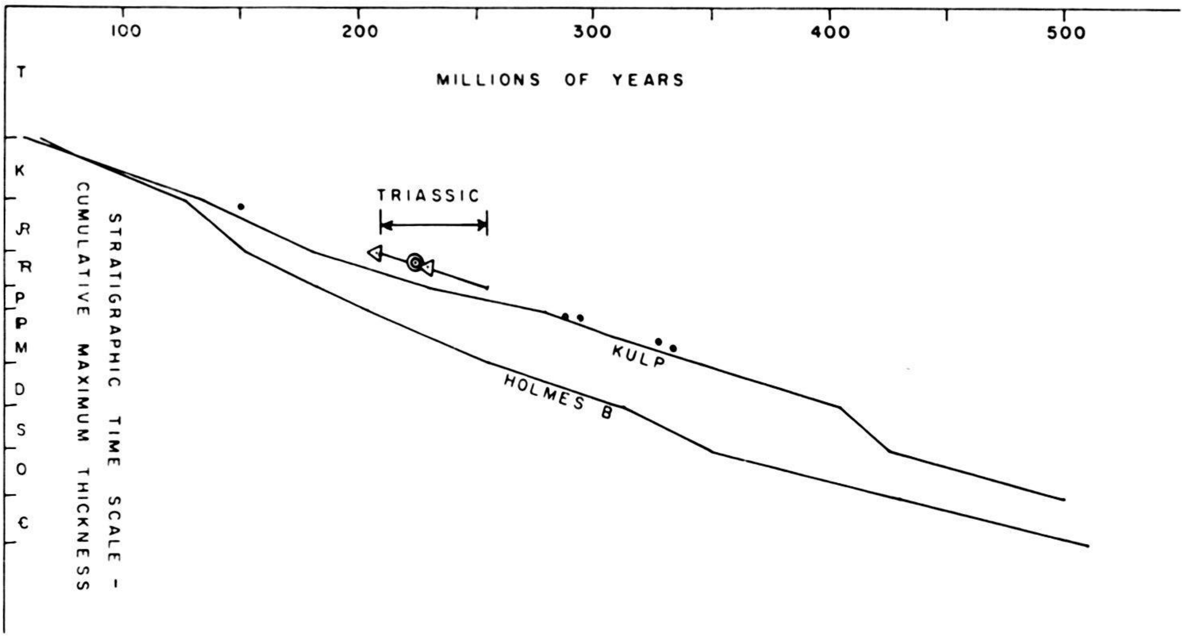

Fig. 4. Graphical illustration of calibration of the geologic time scale. The complete scales of HOLMES (1947) and KULP (1961) are plotted as lines. The triangles represent the post-Upper Triassic plutons of Idaho, and the Middle-Upper Triassic boundary in Italy. The concentric circles are the concentration of high K-Ar dates for dolerite dikes in Connecticut and Pennsylvania. Also plotted are a few other precise time scale points that have been recently reported (BORSI et al., 1966; FITCH and MILLER, 1967; VIALETTE, 1962). The new proposal for the Triassic is in line with revisions of the time scale both before and after it.

conflict with age determinations available for nearby time-scale points. Figure 4 graphically illustrates how the Triassic of this paper relates to some earlier time-scale proposals and some more recent work on critical points, both older and younger. No obvious conflicts are evident; in fact the new data all fall close to a smooth curve when plotted against cumulative maximum thickness – at least a clue that things seem to be going right (although we have no reason to assume that maximum sediment accumulation rates were exactly constant through geologic time).

Conclusion

(a) Study of the Upper Triassic Newark Group volcanic rocks indicates that they are not suitable for defining a point on the geologic time scale. The dates for the Palisades diabase, although reproducible and internally consistent, are all suspect.

(b) The "younger" diabase of the Appalachians are probably Triassic, having been emplaced soon after, or during later stages of Newark Group sedimentation. The magnetic field of the earth apparently fluctuated rapidly during Newark time.

(c) Dating of post-Triassic plutons in western Canada and Idaho as 200 ± 5 and 206 ± 6 m.y. is consistent with an estimate of 210 m.y. for the end of the Triassic. A value of 255 m.y. for the beginning of the Triassic is acceptable, but not proven.

(d) Two unusual dikes in southern Connecticut were also dated. An altered "felsite" described by HOVEY (1897) may belong to the Newark volcanics but an age up to 50 m.y. younger cannot be excluded by the K-Ar date of 180 m.y. A camptonite described by W. L. RUSSELL (1922) was dated 151 m.y., or Late Jurassic. The sample was exceedingly fresh, not showing the alteration always visible in the older rocks but its matrix was glassy and the date may well be somewhat low. It probably is post-Triassic, however. It would be a representative of the mid-Mesozoic White Mountain magma series of the northern Appalachians (RODGERS, 1967), an igneous episode distinctly separate in time, geography, and petrographic character from the Newark Group igneous activity.

(e) Unaltered rock specimens, suitable for definition of the geologic time scale are very rare. The usual criteria for "freshness" of rock specimens are inadequate as screening criteria for dating samples, but a compromise with reality must frequently be made, if we are to progress at all with geochronometric studies. Most dates for older rocks are probably moderately degraded; virtually all K-Ar dates must be viewed with suspicion, particularly those older than 100 m.y.

(f) Many of the youngest K-Ar dates determined in the crystalline rocks of the Appalachians are Triassic, even Late Triassic (ARMSTRONG, 1966; ARMSTRONG et al., in press). They are without doubt much younger than the metamorphism or igneous activity evident in the rocks for which the dates were determined. This is identical with the observation in the Cordillera of the western U.S. that many K-Ar dates for metamorphic rocks are much younger than the metamorphism of the rocks (ARMSTRONG and HANSEN, 1966). In both Appalachian and Cordilleran examples the youngest K-Ar dates for metamorphic rocks indicate that widespread uplift and cooling were synchronous with block faulting and "post-orogenic" volcanism. Continued revision of the geologic time scale during the last two decades has made this "fact of life" painfully clear.

Acknowledgments

The dating studies were financed by NSF grant GP5383; the mass spectrometer was provided by grants from the Research Corporation and the Sheffield Scientific School of Yale University. We thank J. DEBOER, C. W. FIELD, and DEVRIES KLEIN for supplying some of the samples dated. The critical comments of JOHN SANDERS were most helpful. This paper was written while the senior author was an Honorary Fellow in the Department of Geophysics and Geochemistry, Australian National University and help with manuscript preparation is gratefully acknowledged.

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