MIGRATION PATTERNS OF POST-40-MA MAGMATISM IN ARIZONA

by

Stephen J. Reynolds, Frank P. Florence, and Richard A. Trapp

Arizona Geological Survey
Open-File Report 86-6

June, 1986

Arizona Geological Survey
416 W. Congress, Suite #100, Tucson, Arizona 85701

INTRODUCTION

Arizona has experienced widespread magmatism since 40 Ma, when volcanism resumed after a 15 to 20 m.y. hiatus (Damon and Mauger, 1966; Shafiqullah and others, 1980). Magmatism during the past 40 m.y was not evenly distributed across Arizona, but instead migrated between different parts of the State. The patterns of migration are important because they provide insight into the tectonic setting of magmatism and thereby help illuminate the processes responsible for the magmatism and related mineral deposits. In addition, documenting the location of recent volcanism is a necessary step toward evaluating the potential for geothermal energy or volcanic hazards.

In order to accurately characterize the migration patterns of magmatism, we have completed computerized compilations of all published K-Ar, Rb-Sr, U-Pb, and fission-track age determinations in Arizona (Reynolds and others, 1985; Florence and Reynolds, 1985; Reynolds and others, 1986). These computerized databases and graphics programs (Reynolds and Trapp, 1986) have been used to generate page-size maps at several scales showing the distribution of K-Ar ages within Arizona for different time intervals since 40 Ma. We have assembled a number of these maps in this report, and have also included a 1:1,000,000-scale map showing histograms of age determinations within each 1 by 1 degree quadrangle (in pocket). This latter map is especially useful for quickly assessing the magmatic history of any subregion of the state. We have excluded from the plots any dates that were regarded as spurious in the original references or that are markedly inconsistent with observed stratigraphic relationships.

DISCUSSION

Magmatism since 40 Ma can be subdivided into two episodes, one that occurred during Oligocene to mid-Miocene (middle Tertiary) time and another that occurred during mid-Miocene to present time. Most geologists have separated the two magmatic episodes based on a commonly recognizable change from compositionally diverse middle Tertiary magmatic suites to fundamentally basaltic, late Cenozoic suites. The distinction between the two episodes is most obvious by comparing the initial $^{87}Sr/^{86}Sr$ ratio (Sr_o) of post-40-Ma igneous rocks in Arizona. A plot of Sr_o versus age of the rock unit reveals that a fundamental change in magma chemistry occurred at 13 to 15 Ma (Figure 1; see also Annis and Keith, 1986). Magmatic rocks formed prior to this time are characterized by Sr_o of 0.7055 and greater, whereas those formed later have Sr_o of 7055 or less. The 13 to 15 Ma magmatic change is also reflected by major changes in mineralogy, petrochemistry, and metallogeny of the magmatic rocks (Keith and Wilt, 1985; Annis and Keith, 1986). The timing of the switchover varies slightly with geographic area; it is 15 Ma in central Arizona, 13 Ma in west-central Arizona, and probably a similar age in the Lake Mead area. Using these criteria for differentiating the middle and late Tertiary episodes of magmatism permits a more precise evaluation of the time-space migration patterns of both events. The time-space migration patterns of post-40 Ma magmatism, as displayed on the accompanying maps, will be briefly discussed below.

Magmatism between 40 and 33 Ma was centered in southern New Mexico, but extended into eastern Arizona, as represented by dated volcanic and shallow-level plutonic rocks in the Blue Range, Morenci area, and Gila Mountains of east-central Arizona, and the Dos Cabezas, Chiricahua, and southern Pinaleno Mountains of southeastern Arizona. Volcanic rocks of this age also occur at scattered locations in the Pantano Formation and related units near Tucson and further north. Magmatism at 30 to 33 Ma had a similar distribution.

At 30 to 27 Ma, magmatism became more widespread and shifted further westward (Coney and Reynolds, 1977) into the Galiuro, Empire, Santa Rita, Patagonia, Sierrita, and Tucson Mountains of southeastern Arizona. Magmatism continued in the Chiricahua, Dos Cabezas, and Gila Mountains and in the Morenci area. This period of time also marks the first appearance of diffuse volcanism in the Gila Bend and Castle Dome Mountains of southwestern Arizona. Magmatism maintained a similar distribution from 27 and 24 Ma, except became more abundant in the Transition Zone and Colorado Plateau.

The time period between 24 and 21 Ma reveals a major shift of magmatism into central and western Arizona and a marked diminishment of activity in southeastern Arizona. Volcanism was widespread during this interval, occurring in the Galiuro, Tucson, and Roskruge Mountains near Tucson, the Superstition Mountains east of Phoenix, and the Kofa and Ajo volcanic fields of southwestern Arizona. By 21 to 18 Ma, magmatism had ceased most of eastern Arizona, but was intense in the Superior-Ray area and nearby Superstition Mountains, and throughout western Arizona. Magmatism between 18 and 15 Ma became somewhat more restricted to a corridor that stretched along the edge of the Transition Zone from the Superior-Ray area through the Superstition, Hieroglyphic, Wickenburg, and Vulture Mountains and into west-central Arizona.

At 15 Ma, the distribution of magmatism changed dramatically, corresponding to the switch in the type of magmatism to fundamentally basaltic eruptions with low Sr_o. Volcanism between 15 and 12 Ma primarily occurred in west-central Arizona and in the Transition Zone between Phoenix and Flagstaff, where the widespread Hickey Formation basalts were erupted. Volcanism essentially ceased in southern Arizona, except for widely scattered, low-volume eruptions of basalt. This pattern largely continued between 12 and 9 Ma, with a marked locus of bimodal basalt-dacite volcanism near the Verde Valley, along the boundary between the Transition Zone and Colorado Plateau.

Between 9 and 6 Ma, volcanism shifted further northeast, onto the southwestern edge of the Colorado Plateau, which up to this time had largely escaped Mesozoic and Cenozoic magmatism. Basalts of this age are widely distributed from the Shivwits Plateau of northwestern Arizona to the Flagstaff area and into the adjacent Transition Zone. Basaltic rocks of this age are also present north of the Bill Williams River in west-central Arizona and along the Gila River and its tributaries in the Basin and Range Province. A very similar distribution of volcanism continued between 6 and 3 Ma, except for a decrease in basaltic eruptions in west-central Arizona and a slight shift of bimodal basaltic-dacite volcanism to the northeast, further onto the Colorado Plateau. The White Mountains volcanic field of east-central Arizona and the Sentinel-Arlington volcanic field near Gila Bend became fairly active during this time.

Since 3 Ma, volcanism has continued its northeastward shift further into the interior of the Colorado Plateau (Tanaka and others, 1986). Volcanism during this interval was especially robust in the Springerville and San Francisco volcanic fields of the Colorado Plateau and the Arlington and San Bernardino volcanic fields of the Basin and Range Province. Volcanism has continued up to the recent past, when Sunset Crater erupted within the last 1000 years.

(references follow last figure)

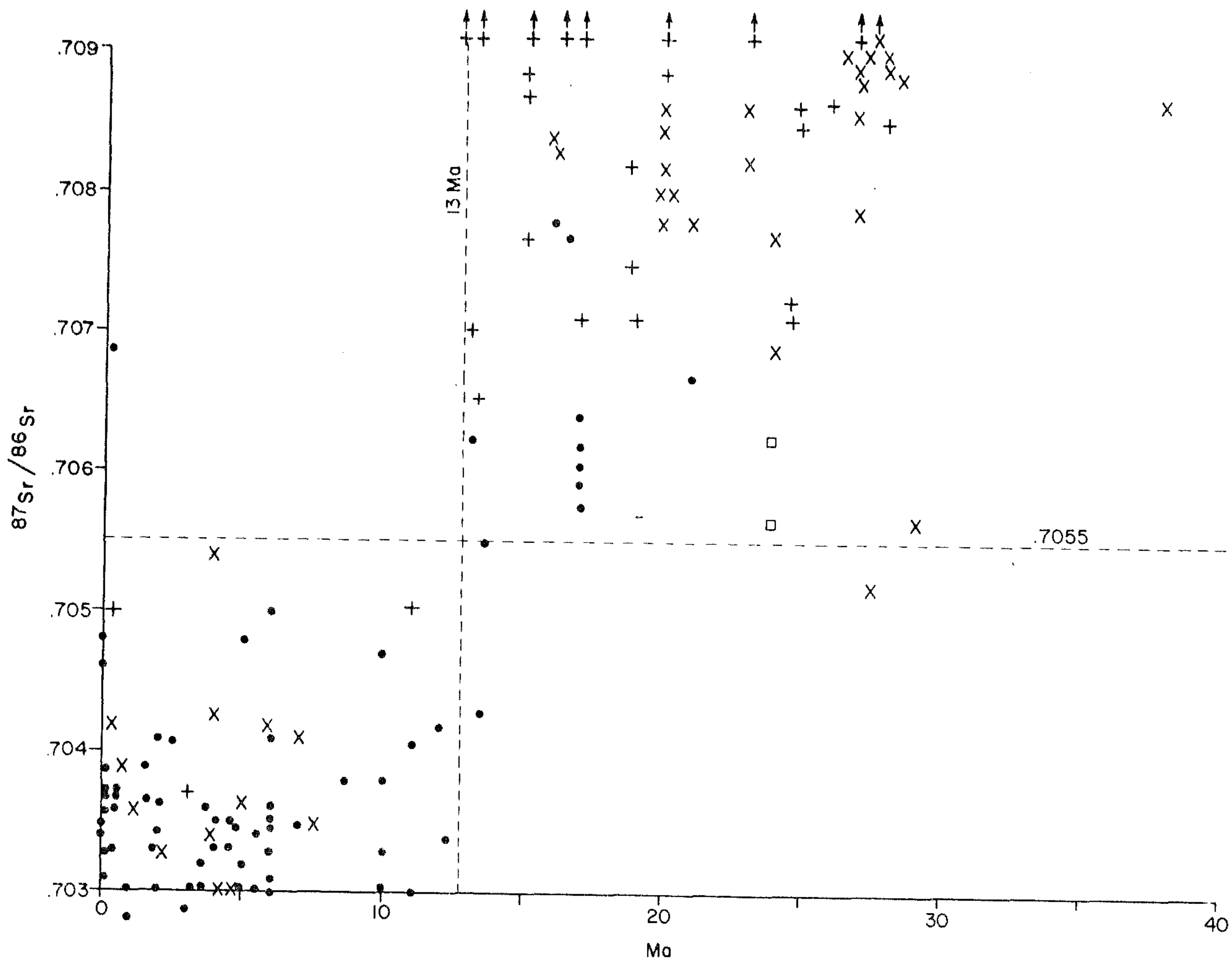
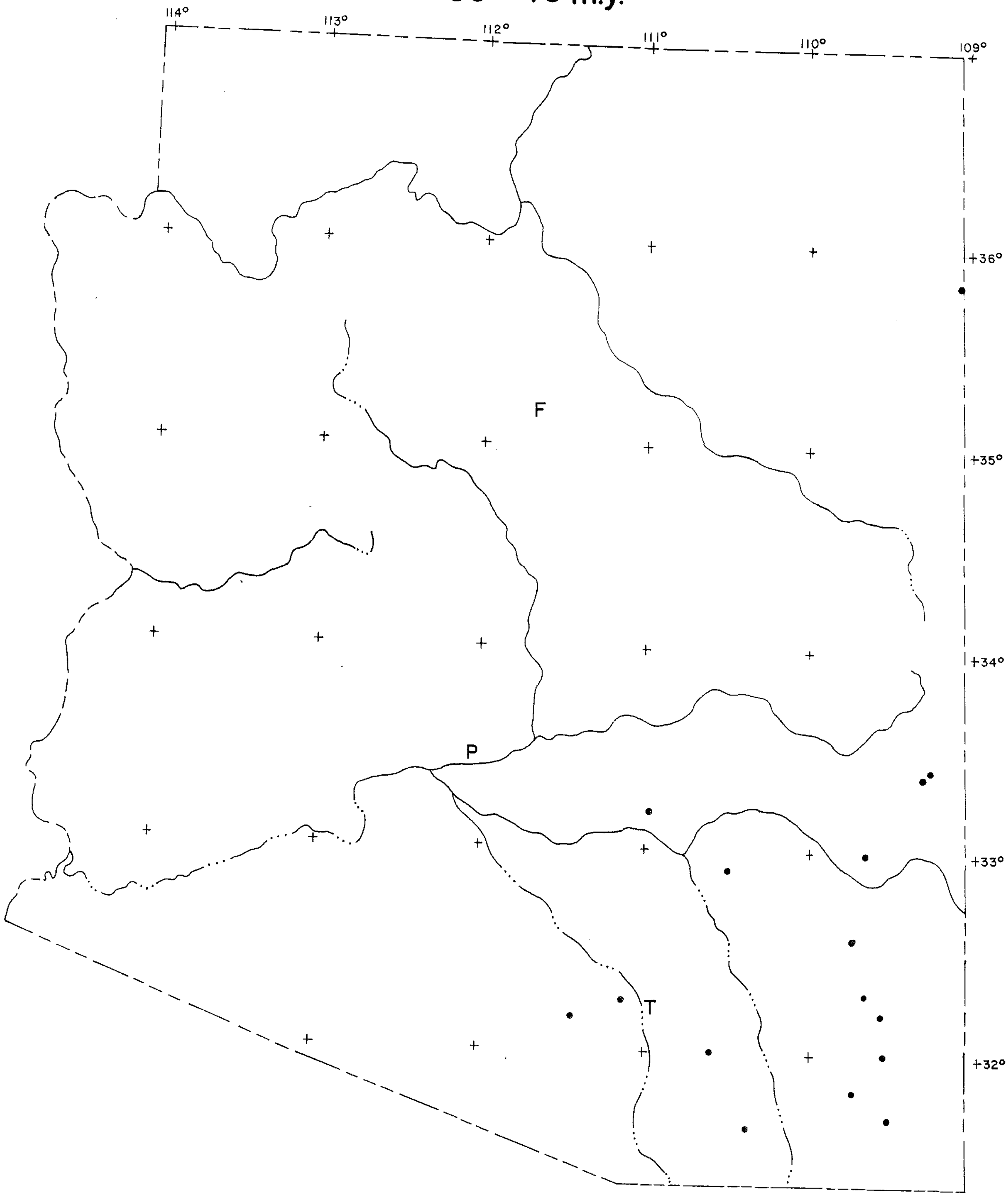
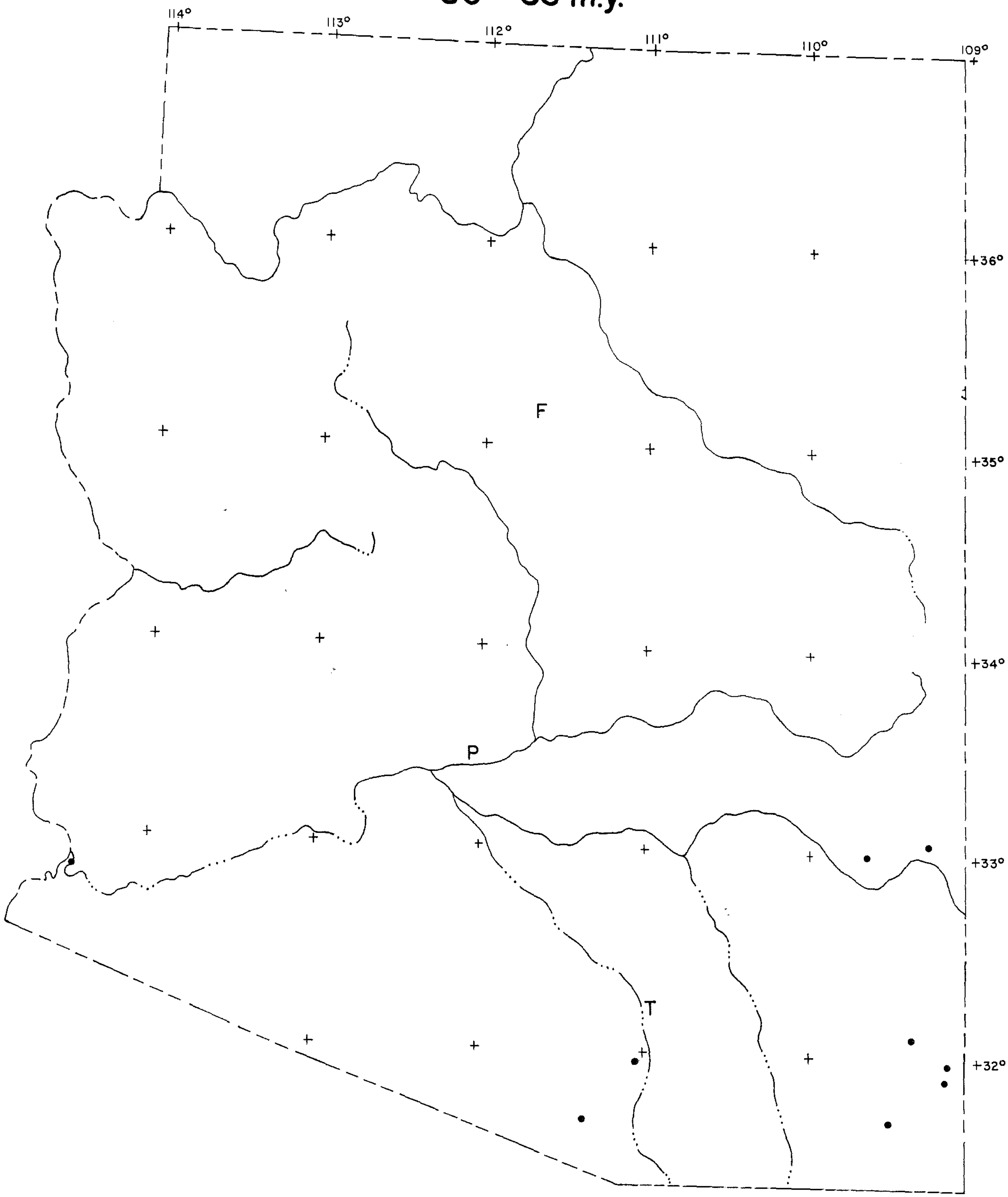


Figure 1. Plot of age versus initial $^{87}Sr/^{86}Sr$ for post-40-Ma igneous rocks in Arizona. Symbols are as follows: dot - basalt, X - andesite and dacite, + - rhyolite and trachyte (including K-metasomatized rocks), and squares - plutonic rocks. Data are from various sources, most of which are listed in Reynolds and others (1985), Florence and Reynolds (1985), or Keith and Wilt (1985). Note that igneous rocks older than 13 to 15 Ma have initial Sr ratios of less than 0.7055, whereas those older than 13 to 15 Ma have higher ratios.

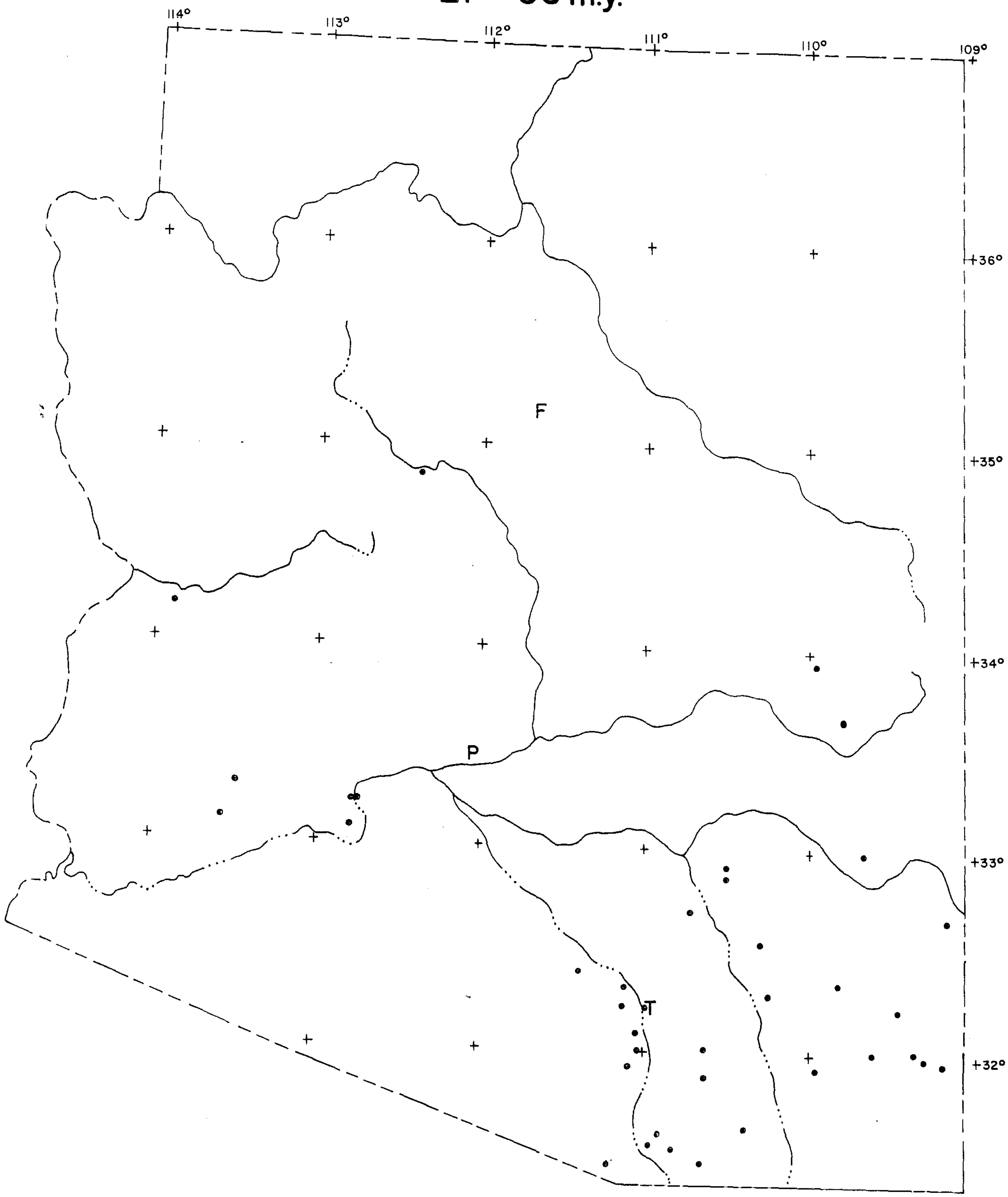
33 - 40 m.y.



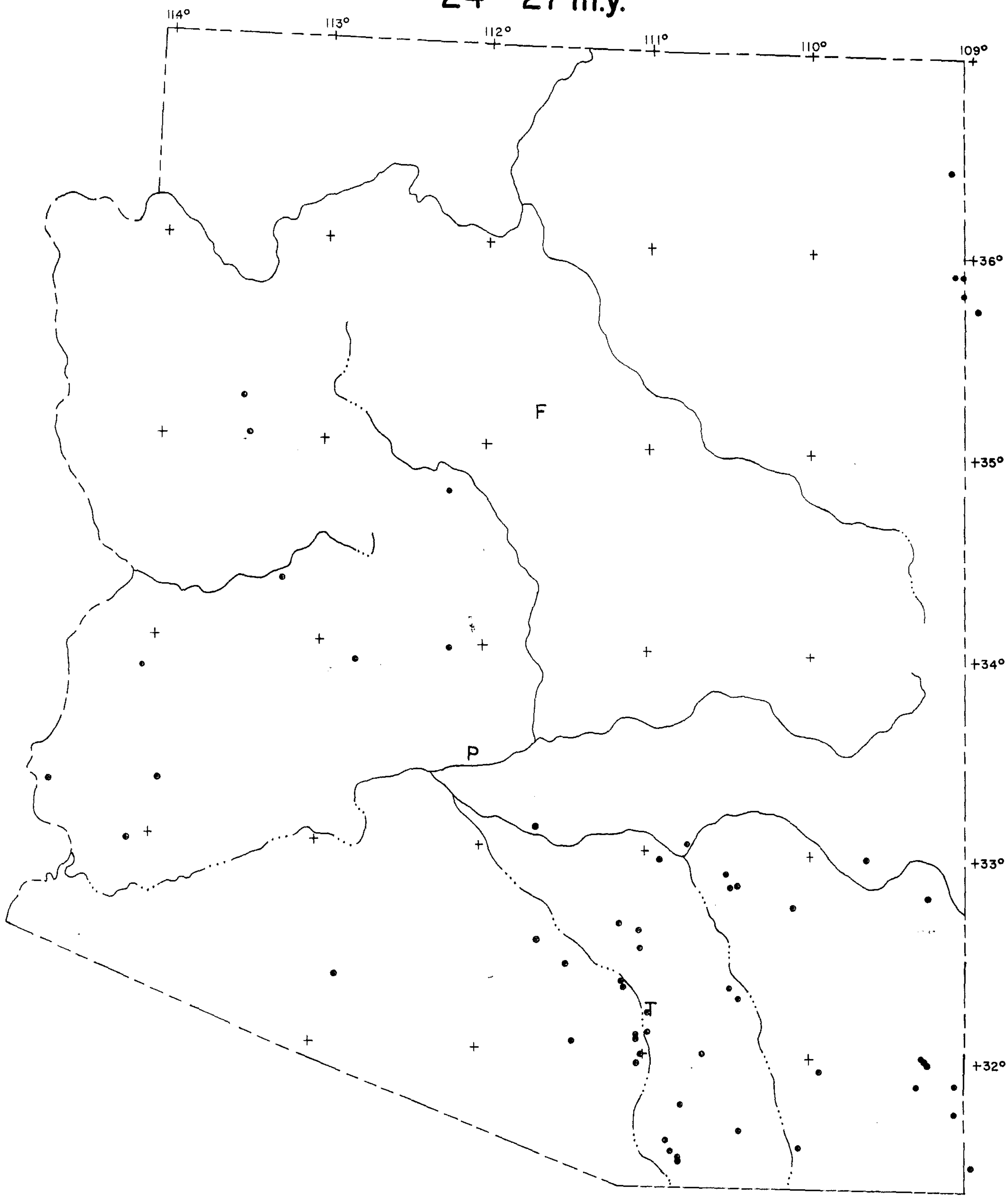
30 – 33 m.y.



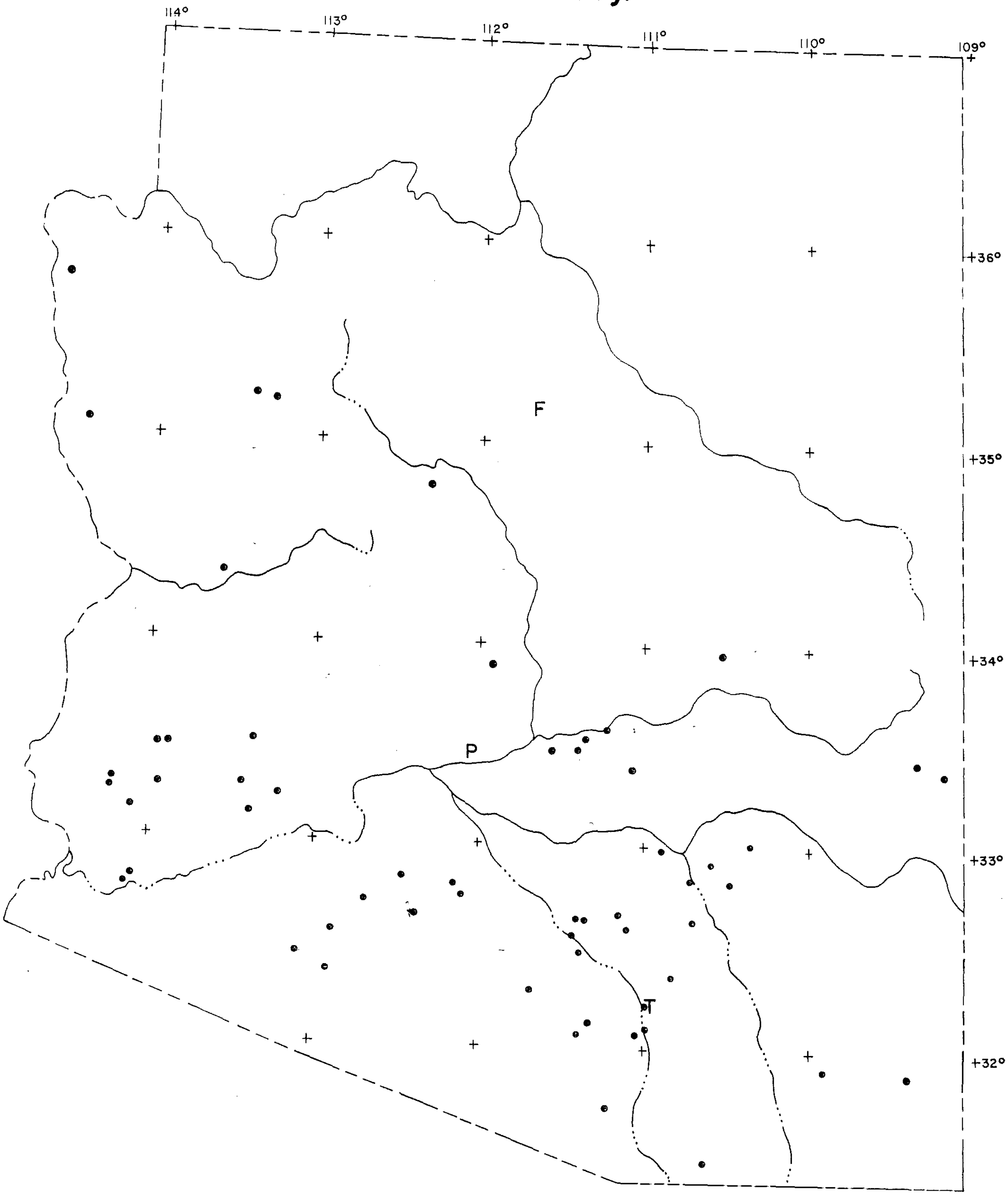
27 – 30 m.y.



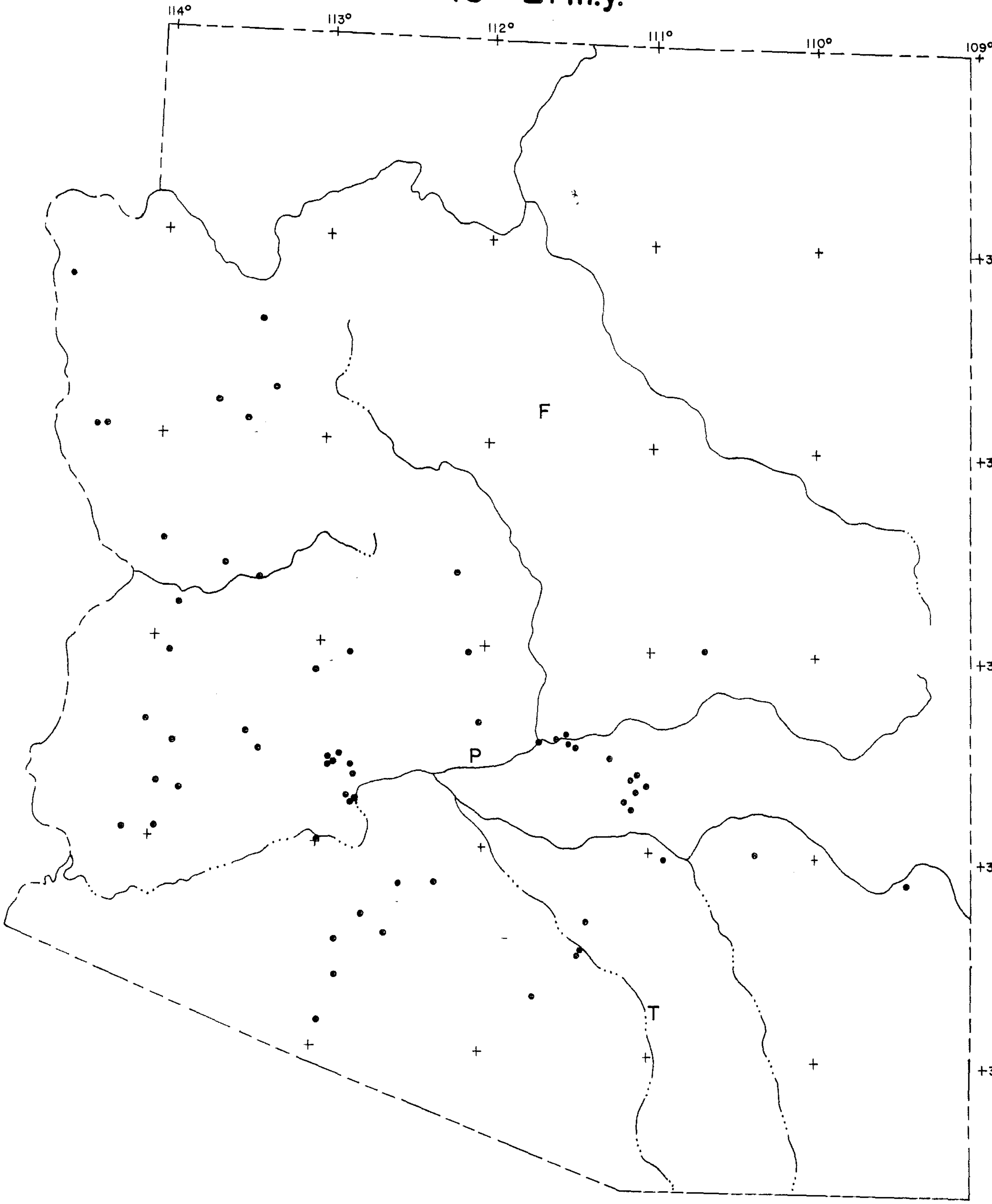
24 – 27 m.y.



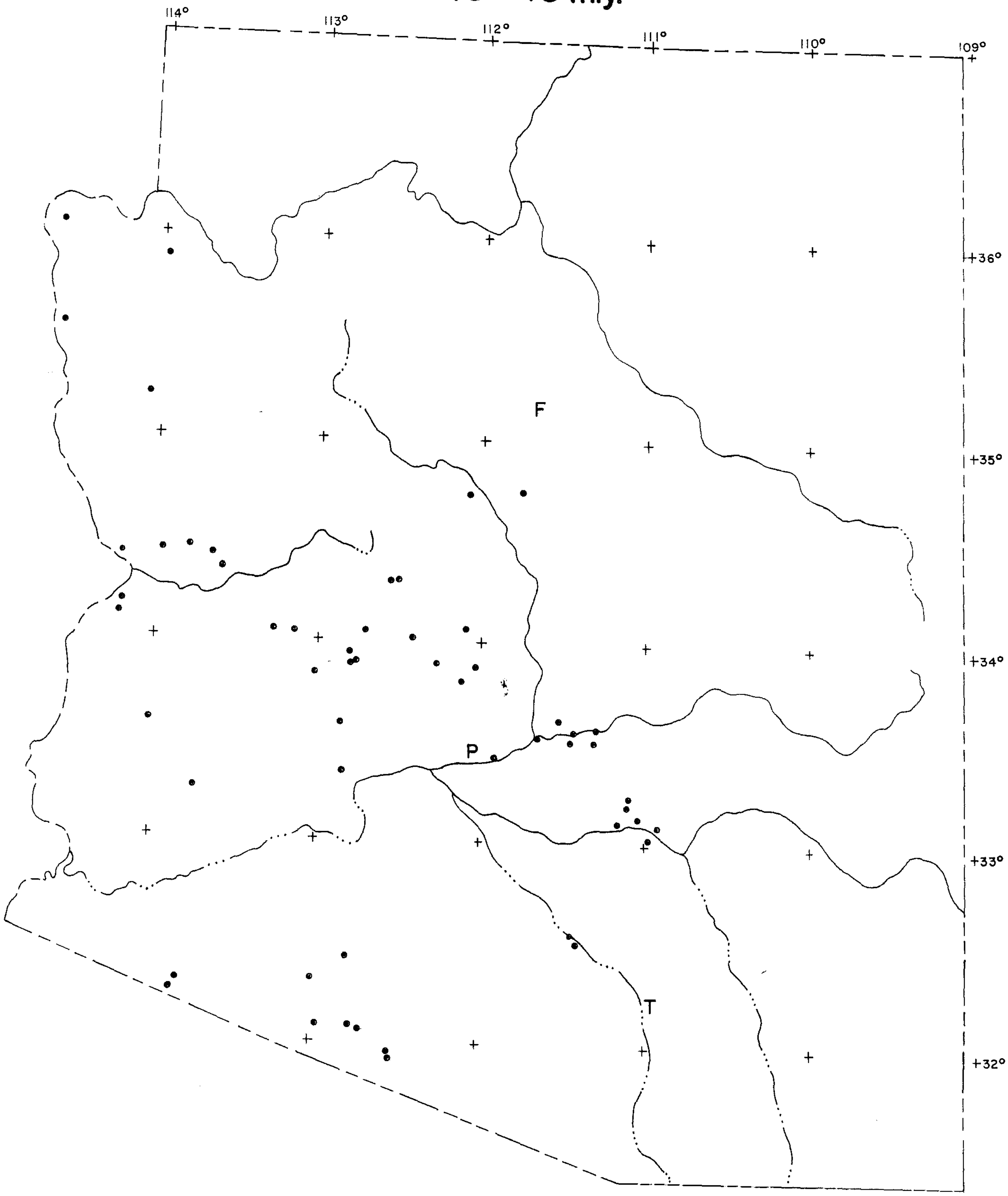
21 – 24 m.y.



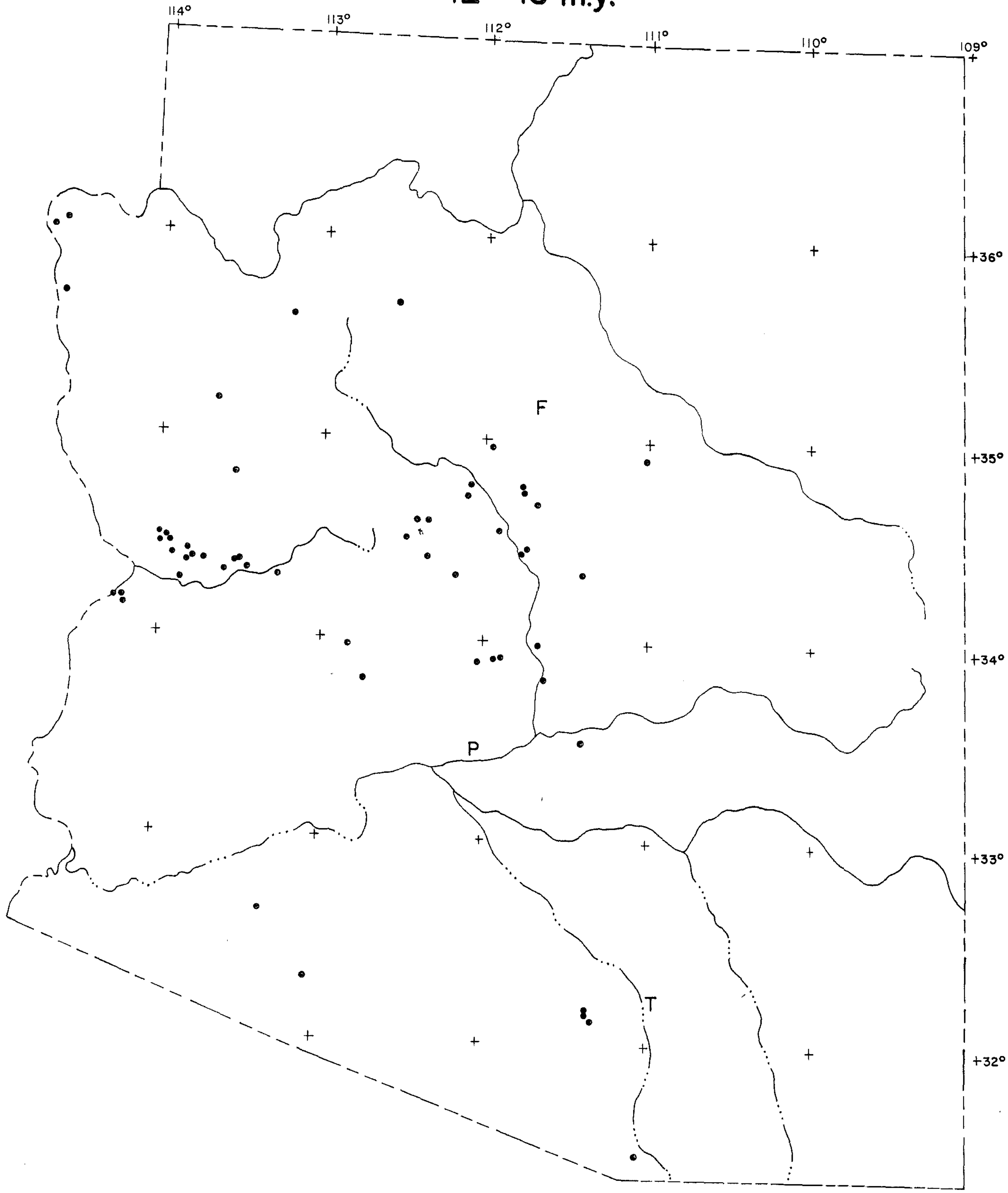
18 – 21 m.y.



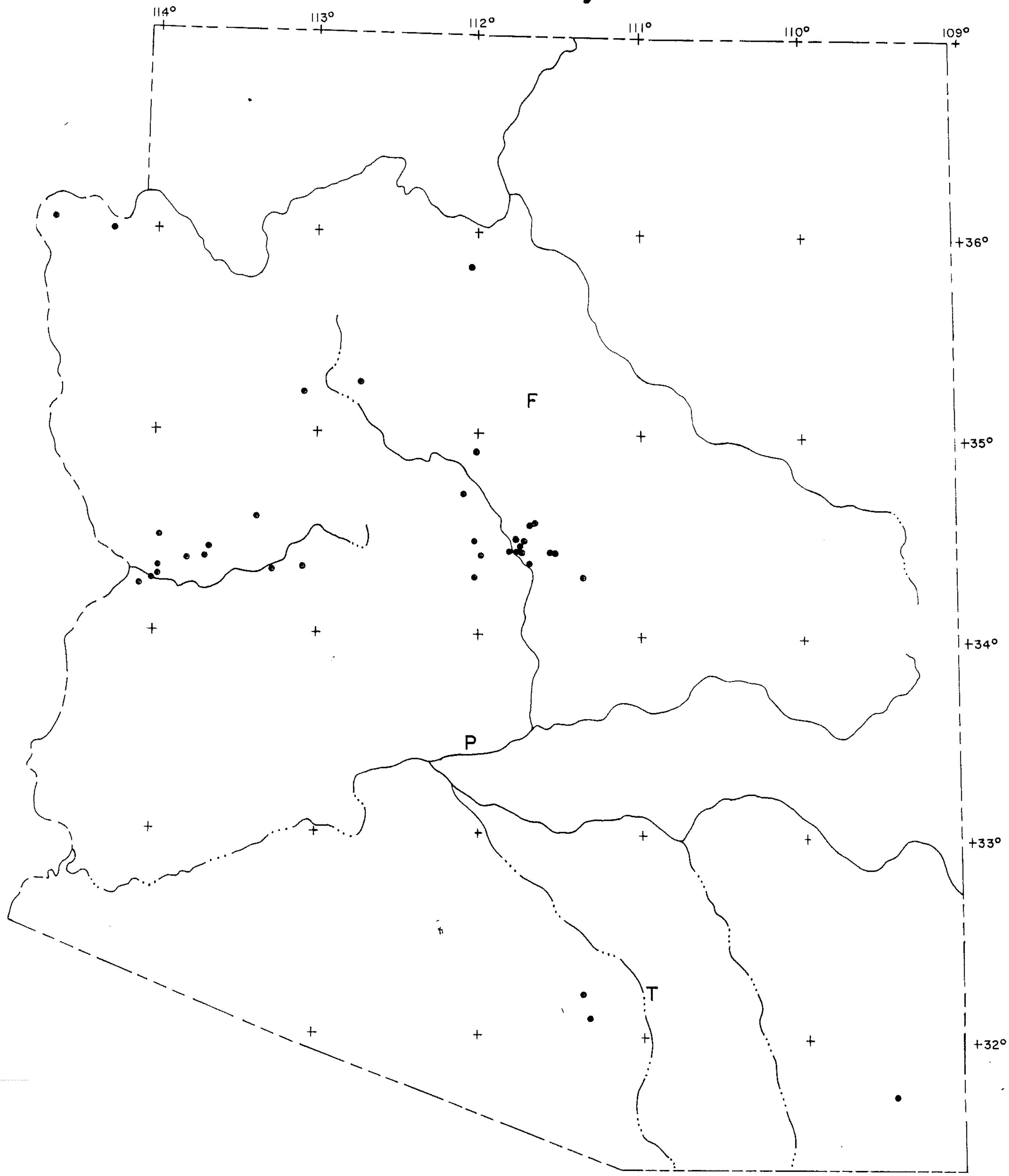
15 – 18 m.y.



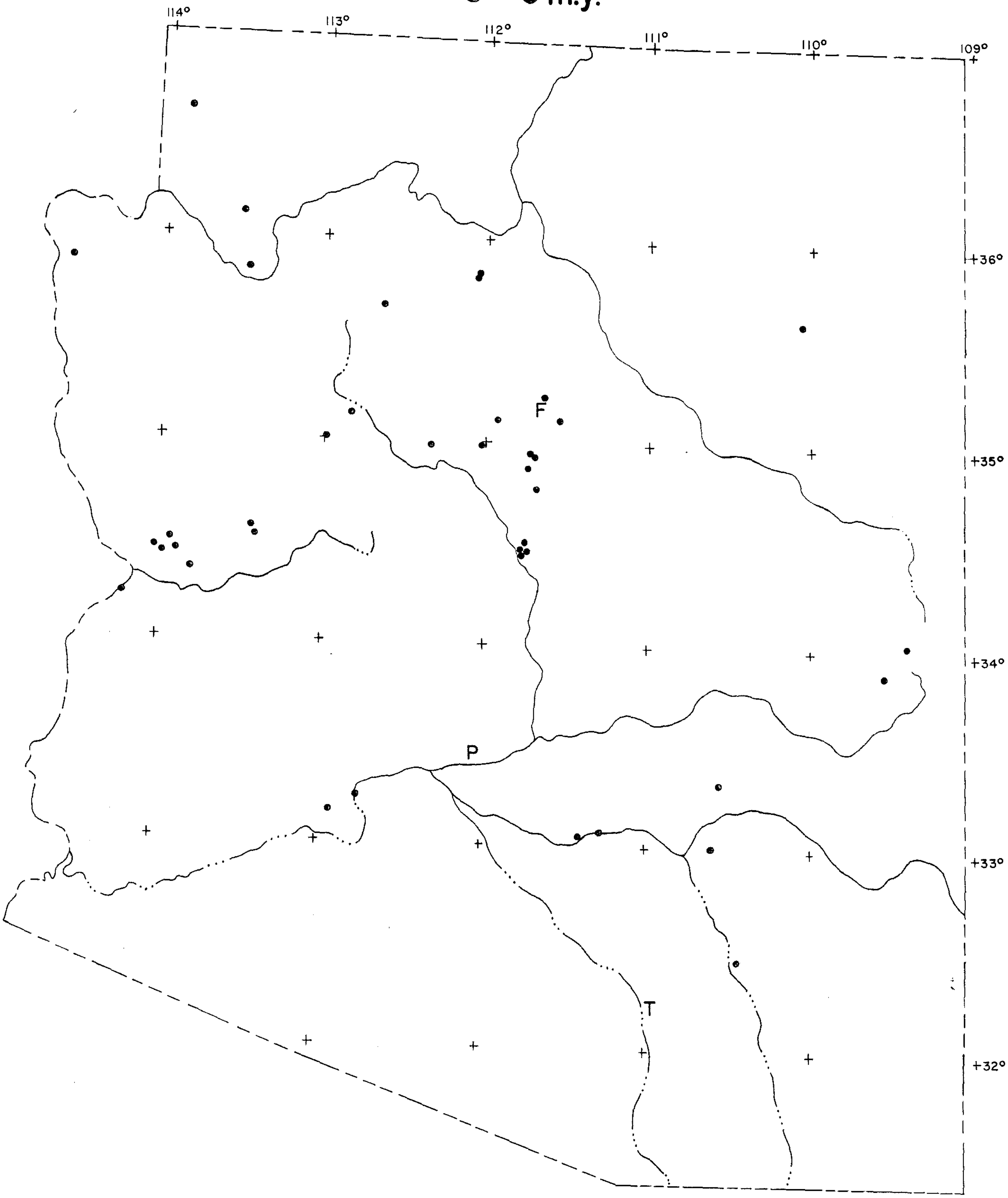
12 – 15 m.y.



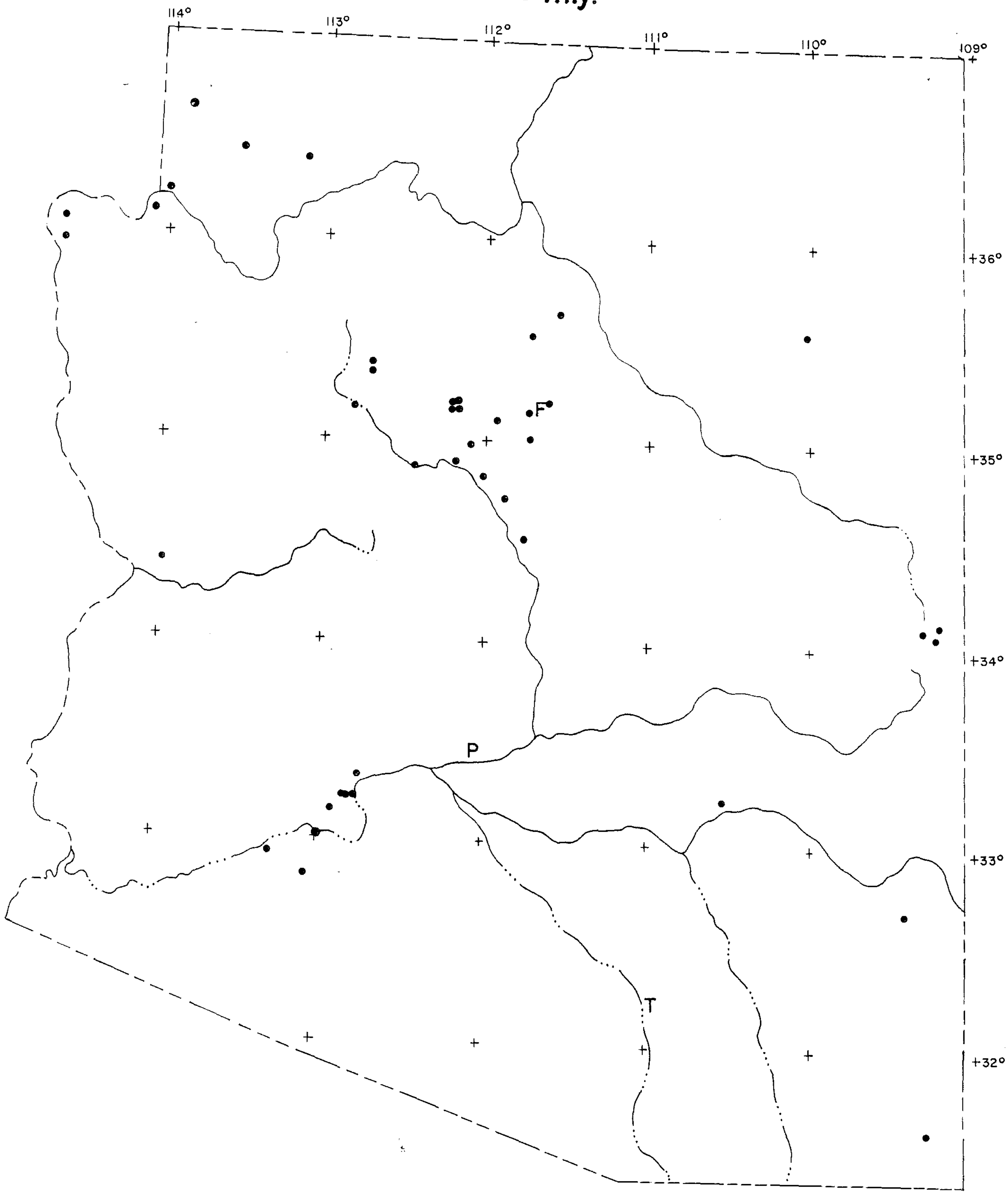
9 – 12 m.y.



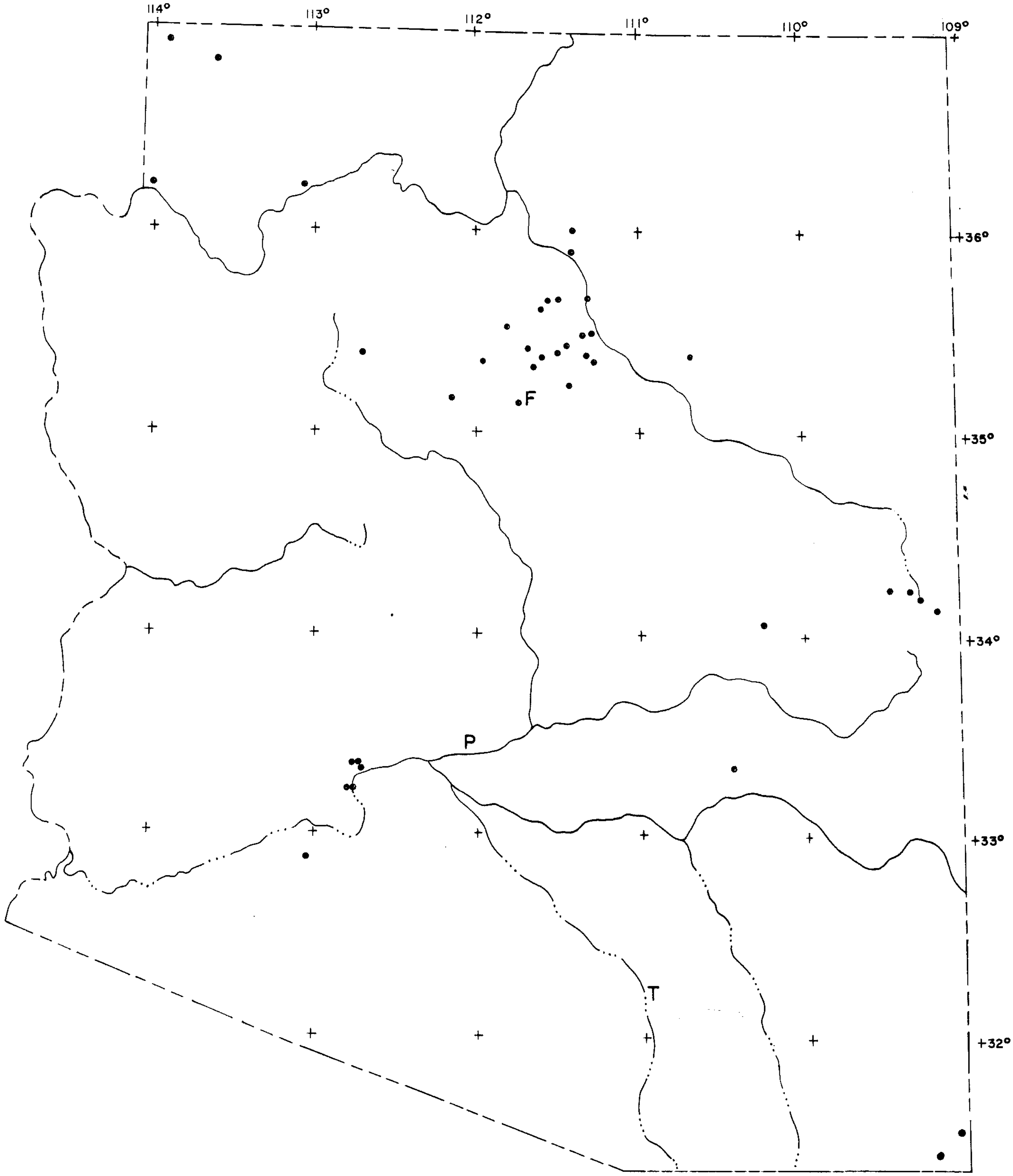
6 – 9 m.y.



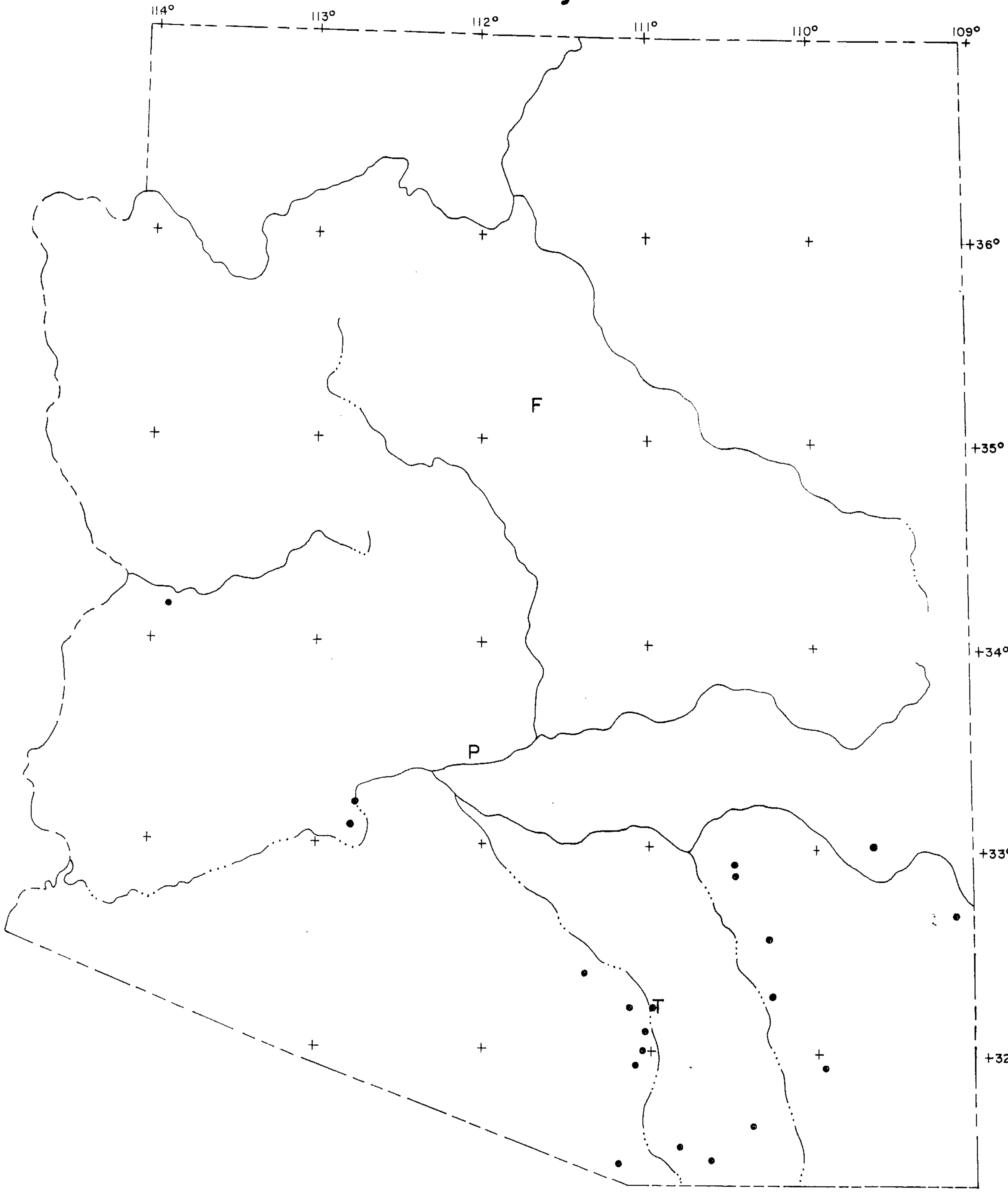
3 – 6 m.y.



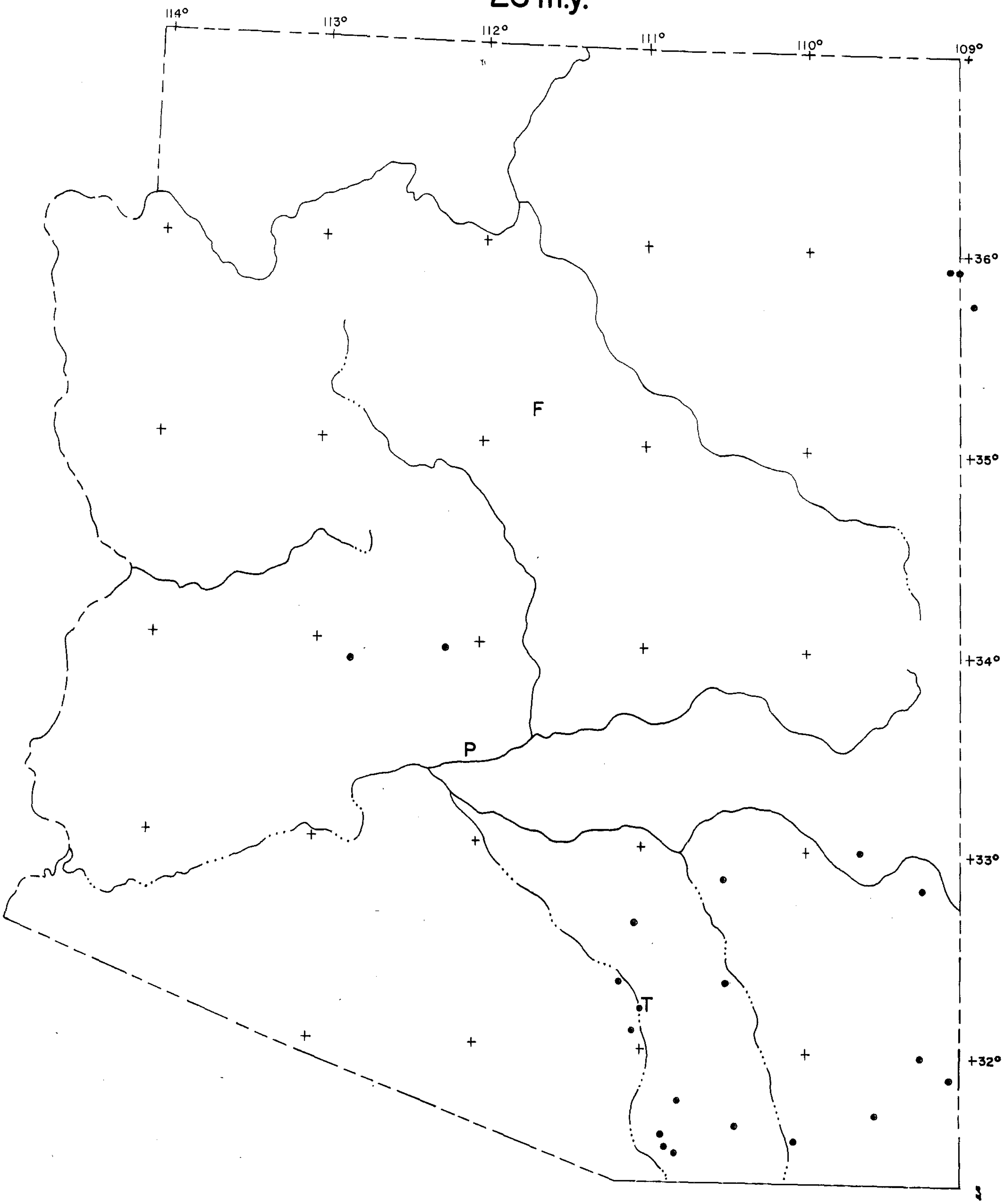
0 – 3 m.y.



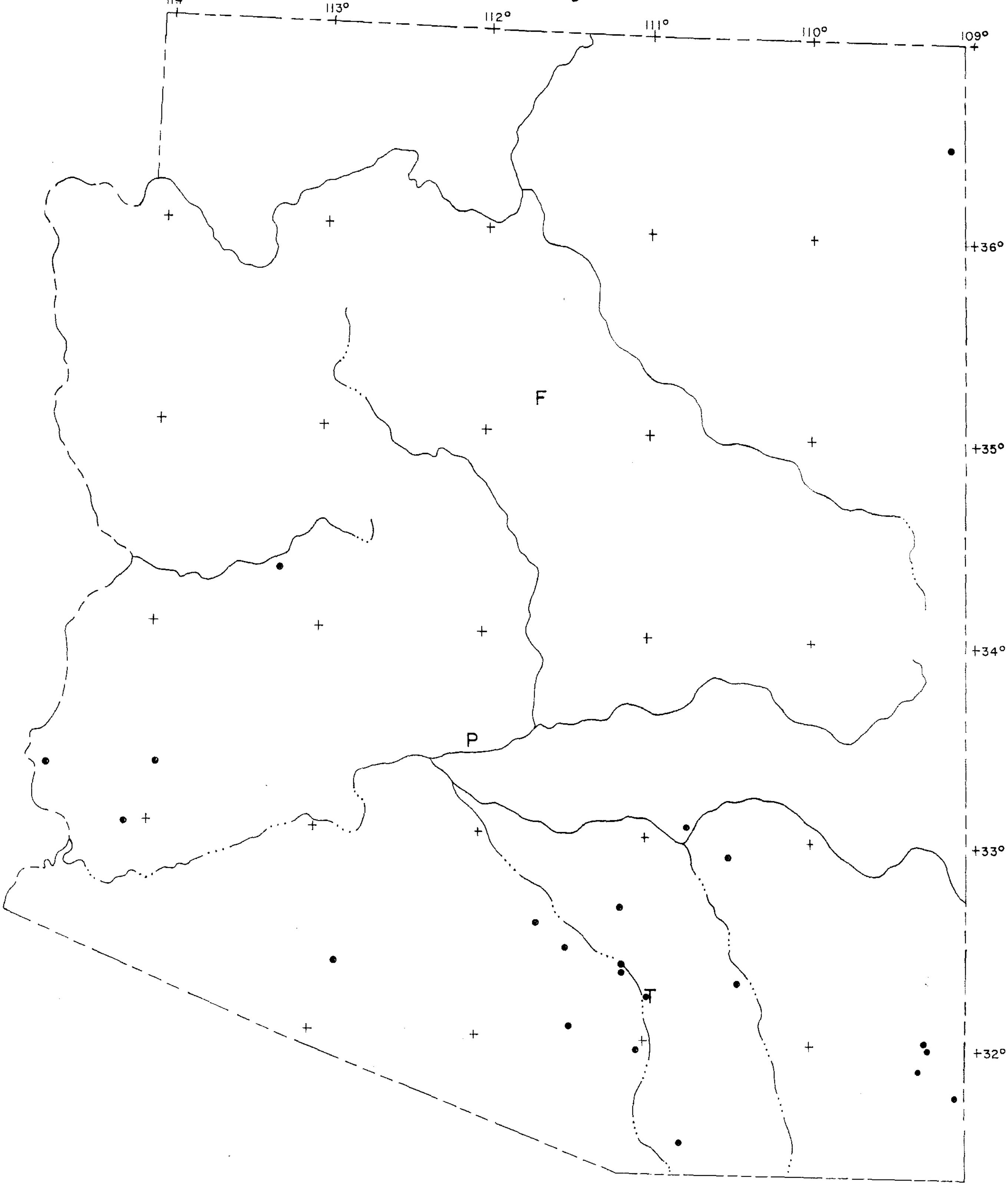
27 m.y.



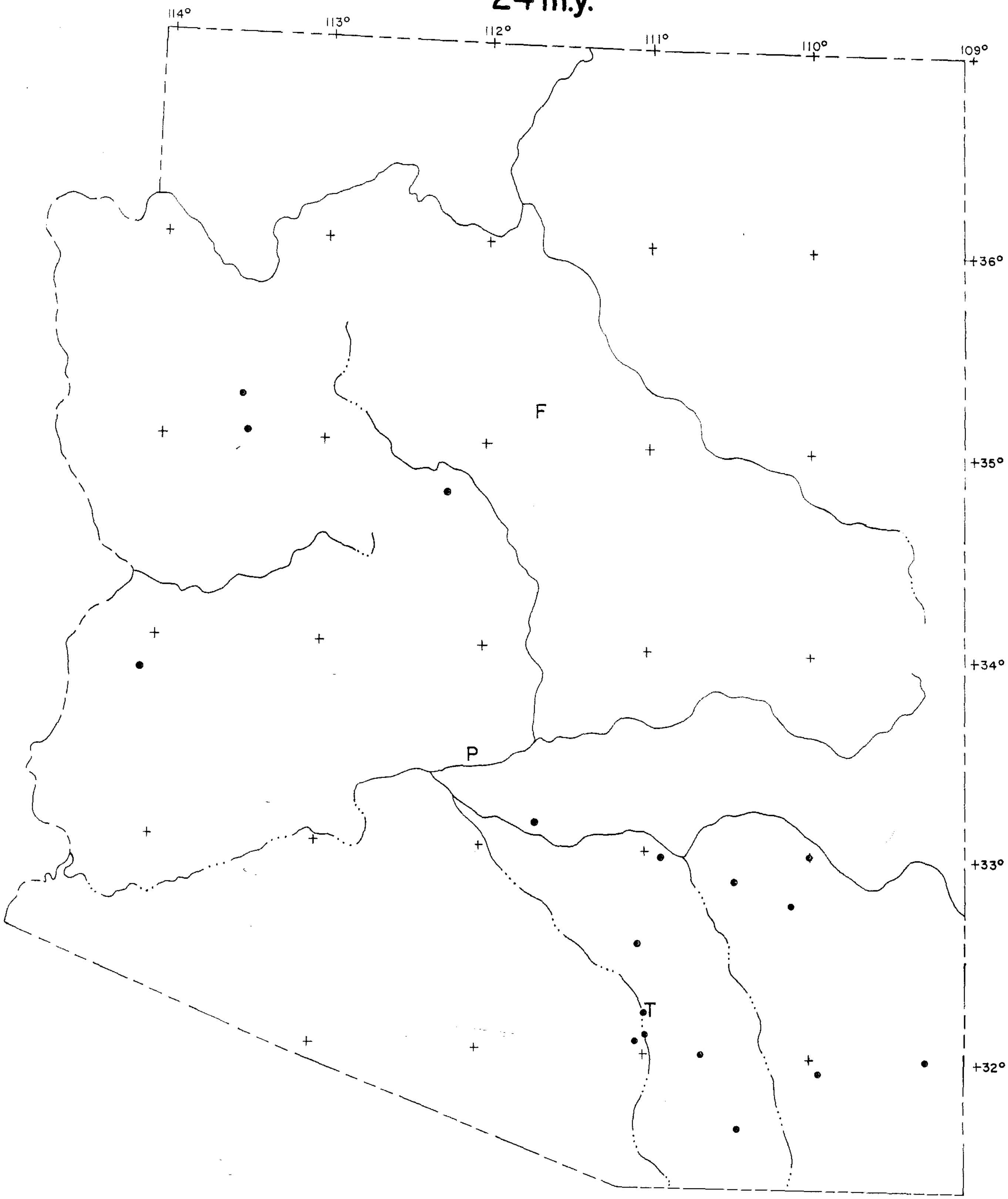
26 m.y.



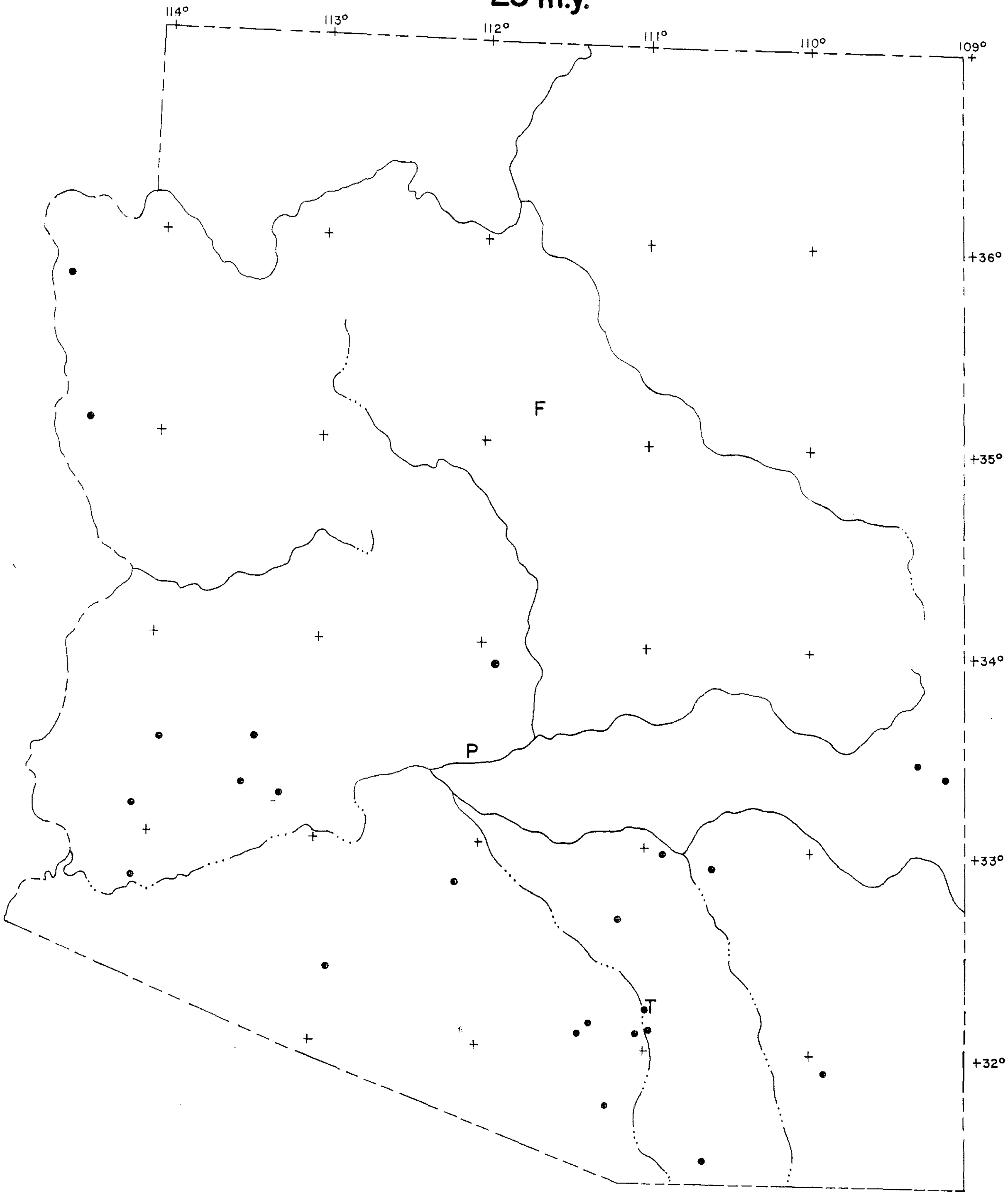
25 m.y.



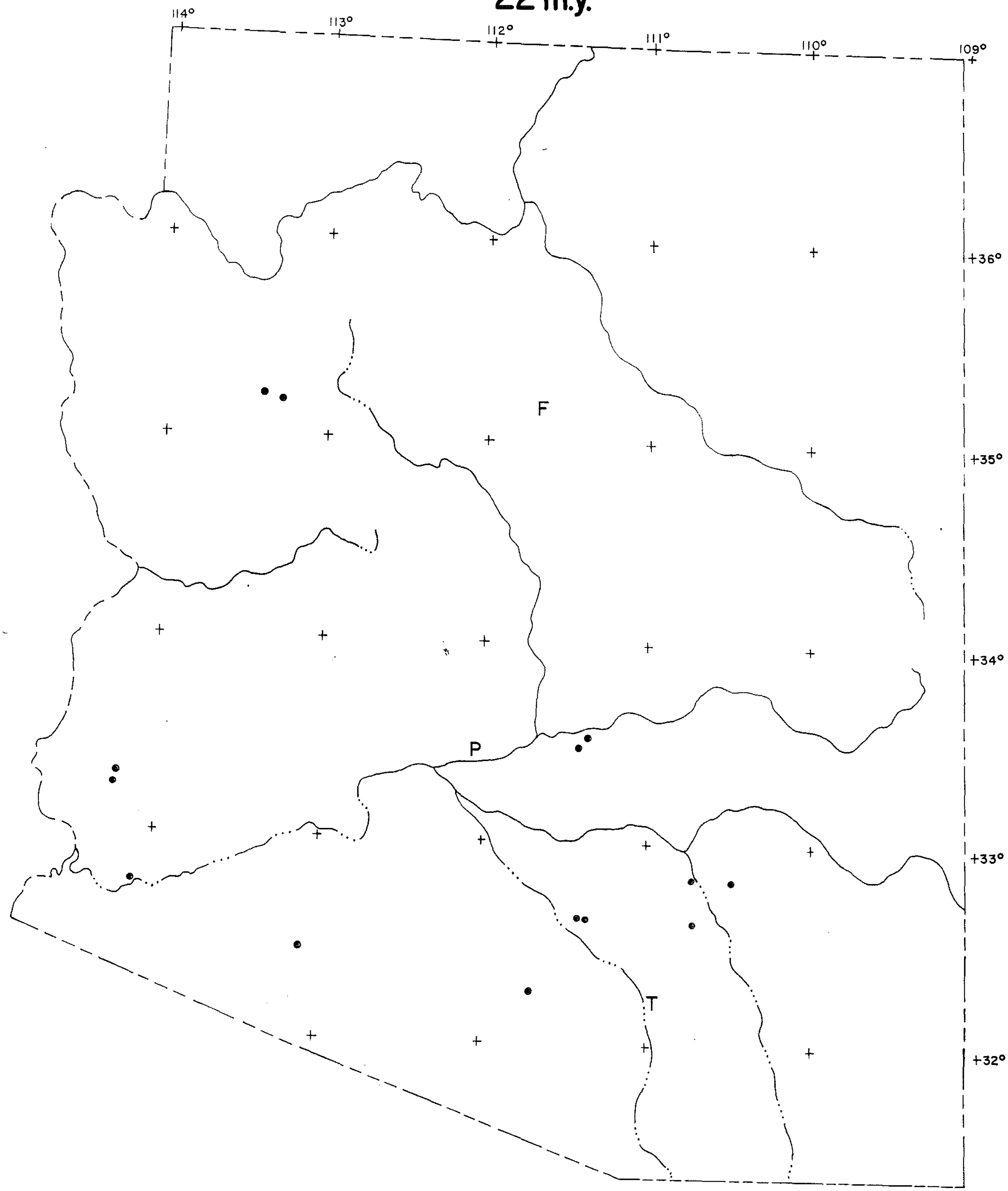
24 m.y.



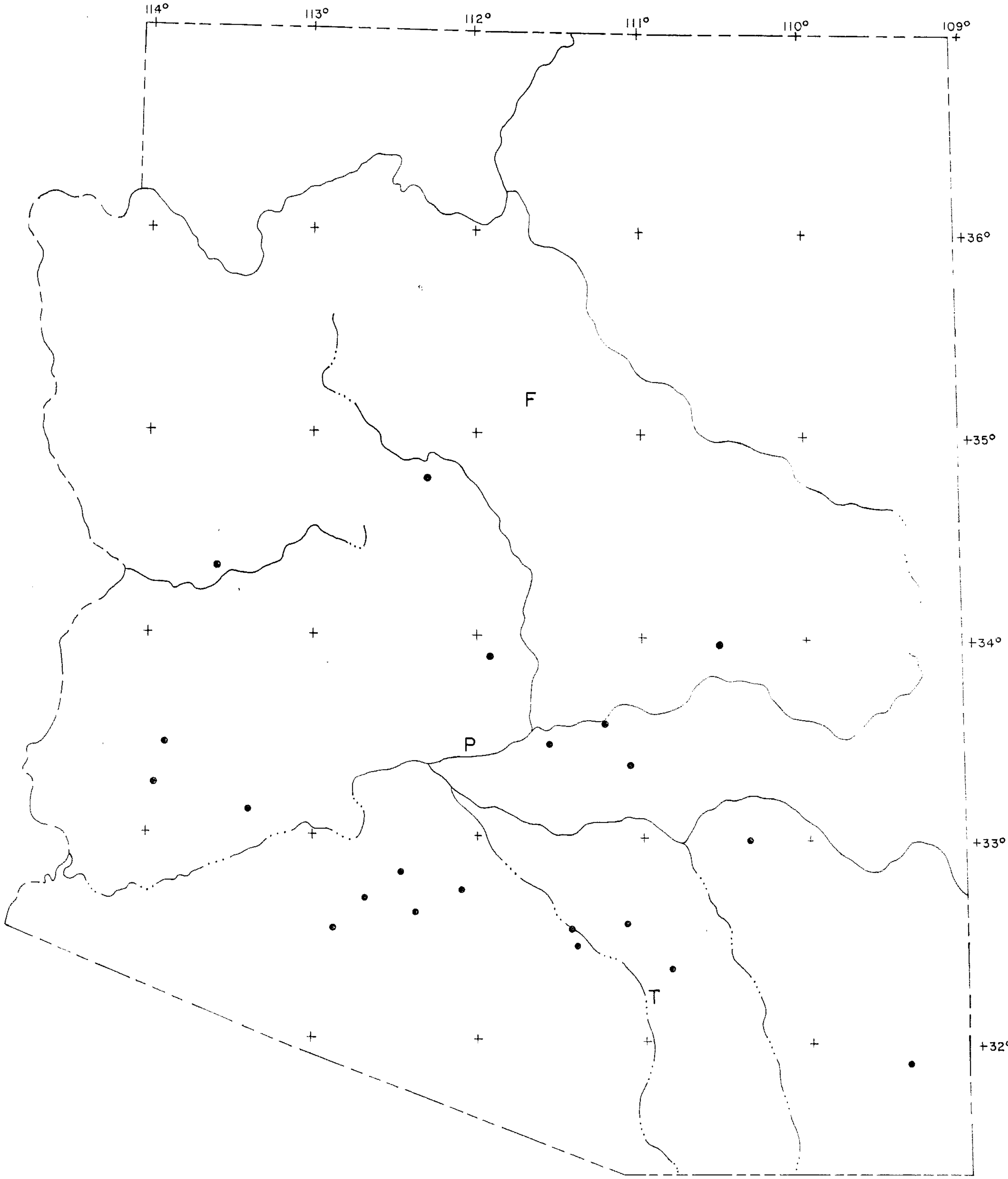
23 m.y.



22 m.y.



21 m.y.



REFERENCES CITED

Annis, D.R., and Keith, S.B., 1986, Petrochemical variation in post-Laramide igneous rocks in Arizona and adjacent regions: geotectonic and metallogenic implications, in Beatty, Barbara, and Wilkinson, P.A.K., eds., Frontiers in geology and ore deposits of Arizona and the Southwest: Tucson, Arizona Geological Society Digest, v. 16, p. 448-458.

Coney, P. J., and Reynolds, S. J., 1977, Cordilleran Benioff zones: Nature, v. 270, p. 403-406.

Damon, P. E., and Mauger, R. L., 1966, Epierogeny-orogeny viewed from the Basin and Range province: Society Metallurgical Engineers Transactions, v. 235, p. 99-112.

Florence, F. P., and Reynolds, S. J., 1985, Compilation of Rb-Sr, fission-track, isotopic lead, and lead-alpha age determinations in Arizona: Arizona Bureau of Geology and Mineral Technology Open-File Report 85-18, 89 p.

Keith, S. B., and Wilt, J. C., 1985, Late Cretaceous and Cenozoic orogenesis of Arizona and adjacent regions: A strato-tectonic approach, <u>in</u> Flores, R. M., and Kaplan, S. S., eds., Cenozoic paleogeography of west-central United States: Society of Economic Paleontologists and Mineralogists, Rocky Mountain Section, p. 403-437.

Reynolds, S. J., Florence, F. P., Currier, D. A., Anderson, A. B., Trapp, R. A., and Keith, S. B., 1985, Compilation of K-Ar age determinations in Arizona: Arizona Bureau of Geology and Mineral Technology Open-File Report 85-8, 320 p.

Reynolds, S. J., Florence, F. P., Roddy, M. S., and Trapp, R. A., 1986, Preliminary map of K-Ar age determinations in Arizona: Arizona Bureau of Geology and Mineral Technology Open-File Report 86-3, scale 1:500,000.

Reynolds, S. J., and Trapp, R. A., 1986, Computerized databases and database-access programs of the Arizona Geological Survey: Arizona Bureau of Geology and Mineral Technology Open-File Report 86-7.

Shafiqullah, M., Damon, P. E., Lynch, D. J., Reynolds, S. J., Rehrig, W. A., and Raymond, R. H., 1980, K-Ar geochronology and geologic history of southwestern Arizona and adjacent areas in Jenney, J. P., and Stone, Claudia, eds., Studies in western Arizona: Arizona Geological Society Digest, v. 12, p. 201-260.

Tanaka, K. L., Shoemakeer, E. M., Ulrich, G. E., and Wolfe, E. W., 1986, Migration of volcanism in the San Francisco volcanic field, Arizona: Geological Society of America Bulletin, v. 97, p. 194-205.