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# HIGH FLUORINE CONTENTS IN THE PLIOCENE VOLCANIC ROCKS OF THE GOLCUK AREA, ISPARTA, SW TURKEY

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**ABSTRACT**

The Gölcük area in central Anatolia represents a post tectonic Pliocene volcanism upon a Mesozoic paleorift in the entire Taurides margin. In this connection the tectonic structures of the region result from the main alpine orogenic phases of the Helleno-Tauric belt. The study area consists of sedimentary and volcanic rocks. As allochthonous, the Triassic through Upper Cretaceous Akdag-limestone and the Upper Cretaceous to Lower Tertiary volcano-sedimentary series constitute the basement rocks. They are transgressively overlain by marine clastic series of Eocene and conglomerate of Oligocene age. The volcanic rocks are tephriphonolite (stage i), pyroclastic series represented by friable tuff, ignimbrite, and pumice tuff (stage ii), and trachyandesite with trachyte (stage iii) as vents, dikes, and volcanic domes. They indicate a sodic alkaline character.

As F-bearing minerals, the volcanics consist of pyroxene, hornblende, biotite, fluorapatite, and extreme small fluorite crystals. Additionally, the glassy groundmass can be added to the F-carriers. The F-contents in the volcanic rocks show a close correlation with $P_2O_5$ and are generally controlled by fluorapatite consequently. This assumption can be established by the predominance of high REE contents. Moreover, it is a novelty that the F-contents display a remarkable depletion from basic towards the acidic rocks which might be attributed to discharging of the F portions during fumarolic activity.

**INTRODUCTION**

The Gölcük area, situated in the SW part of the province capital Isparta (Fig. 1), represents a post tectonic Pliocene volcanic field upon a Mesozoic paleorift in the western Taurides (POISSON et al. 1984), the so called Isparta angle between Lycian and Hadim-Hoyran-Beysehir nappes (ÖZGÜR et al. 1990). The tectonic structures of the region results from the main alpine orogenic phases of the Helleno-Tauric belt (KISSEL et al. 1989). From Paleocene through Quaternary, an extensive volcanic activity took place in central Anatolia (INNOCENTI et al. 1975; ERCAN 1986) which is related to the Afro-Arabian plate being subducted under the Euro-Asiatic plate. The volcanic rocks of the Gölcük area belong to a Pliocene sequence.

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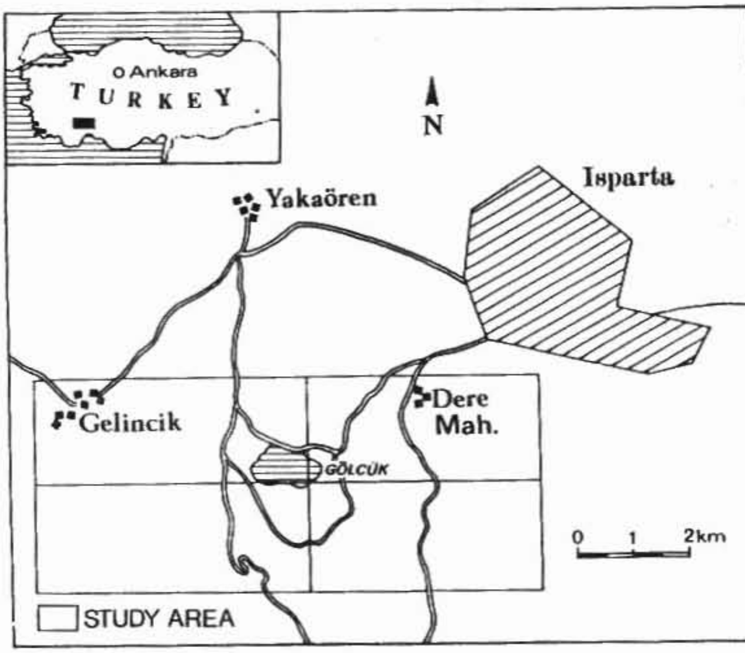


Fig. 1: Location map of the Gölcük area, Isparta, SW Turkey

Due to high fluorine contents in shallow aqueous systems as drinking water of the Gölcük area up to 6 mg/l we investigated the whole rock series, especially the volcanic rocks (ÖZGÜR et al. 1990; PEKDEGER et al. 1990, 1992). The aim of this paper is to elucidate the origin of the high fluorine contents in the volcanic rocks and the evolution of volcanic activity in the Gölcük area, because the shallow aqueous systems in the area is characterized by unusually high fluorine contents.

## GEOLOGIC SETTING

In the study area, the basement rocks are the Triassic through Upper Cretaceous Akdag-limestone and the Upper Cretaceous to Lower Tertiary volcano-sedimentary series which are considered as allochthonous. Stratigraphically, they are transgressively overlain by marine clastic series of Eocene and conglomerate of Oligocene age. The volcanic rocks in the area belong to Lower Pliocene sequence from 4.07 ± 0.20 to 4.70 ± 0.50 Ma (LEFEVRE et al. 1983).

The volcanic rocks consist of lava flows and pyroclastic series. The lava flows are tephriphonolite, trachyandesite, and trachyte, as indicated by more than 60 rock analyses (PEKDEGER et al. 1992; Fig. 2; Tab. 1). The outcrops of tephriphonolite around the caldera now occupied by Gölcük lake constitute the first volcanic stage. The second stage is strongly characterized by volcanic explosions around the center of the recent Gölcük caldera. As third volcanic stage, trachyandesites and trachytes occur as different extrusions in size and shape of vents, dikes, and volcanic domes.

The second volcanic stage is represented by a pyroclastic sequence constituted by friable tuff (150 m), ignimbrite (20 m), and pumice deposit (10 m) exhibiting a composition ranging from trachyandesites to trachytes (Fig. 2). They are believed to be source of the high fluorine contents in the shallow aqueous systems in this area (PEKDEGER et al. 1992). The friable tuff is the greater part of the pyroclastic series and contains levels rich in lapillis and bombs.

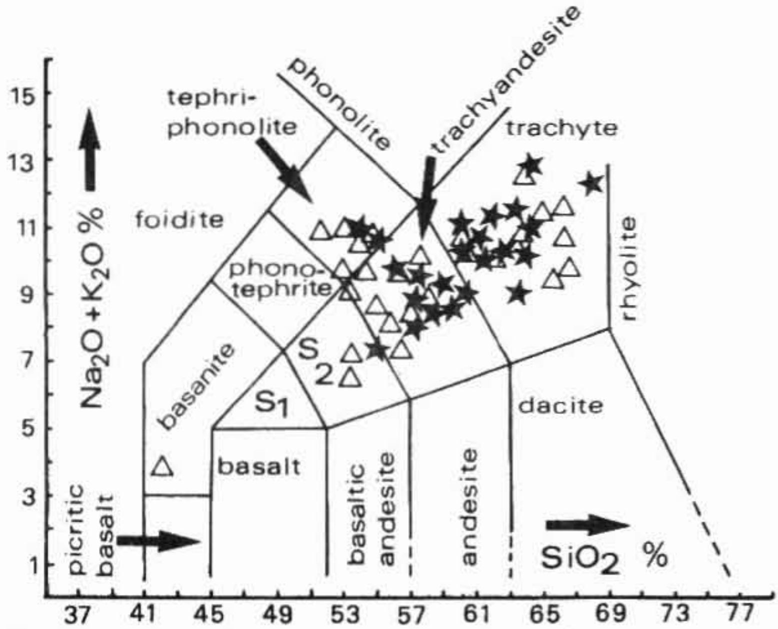


Fig. 2: Discrimination of the Gölcük lava flows (△) and pyroclastic series (★) according to the classification scheme of LE MAITRE (1984). $S_1$: trachybasalt; $S_2$: benmoreite (Na) or shoshonite (K).

Moreover, the Akdag-limestone, the clastic materials of serpentinite and radiolarite, and relicts of tephriphonolite and xenoliths as deep-seated rocks are incorporated in friable tuff. In comparison to friable tuff, the ignimbrite distinguishes by its coarse and unsorted occurrence. The pyroxenitic xenoliths occur only in pyroclastic series sporadically and consist of pyroxene with inclusions of fluorapatite, orthoclase, olivine, anorthite, nepheline, ilmenite, and magnetite.

Generally, the volcanic rocks consist primarily of varying constituents of K (Na)-sanidine, oligoclase, pyroxene, biotite, hornblende, pyroxenitic xenoliths, glassy groundmass, and minor quantities of fluorapatite, fluorite, and sphene commonly. Moreover, the tephriphonolite contain augite and nepheline additionally. As an important F-tracer in the volcanic rocks, fluorapatite can be observed microscopically (Fig. 3), which shows geochemically a depletion of fluorine contents from the basic towards to the acidic rocks generally.

## SAMPLING AND ANALYTICAL METHODS

For the rock analyses, 217 samples have been obtained from the Gölcük-lake area and its environs (PEKDEGER et al. 1992). The rock sampling has been taken place according to the principle representative sample of each rock formation. Major and some trace elements (Ba, Sr, Rb, Cr, Co, Ni, Zr, and Th) were determined by X-ray fluorescence spectrometry at the Institut für Chemie, Freie Universität Berlin, with a routine precision better than ± 5 % for most elements (Tab. 1).

Rare earth elements (La, Ce, Sm, Eu, Tb, Yb, and Lu) were determined by instrumental neutron activation at the Hahn-Meitner Institut für Kernforschung, Berlin, with a routine precision better than ± 9 % for most elements (DULSKI and MÖLLER 1975) using GSP-1 of U.S. Geological Survey as the reference standard. Cu, Pb, and Zn were determined by atomic absorption, and F by ion-sensitive electrode at the Institut für Geologie, Geophysik und Geoinformatik, Freie

Universität Berlin, with a precision better than ± 5 %. For all analyses, BCR-1 and GSP-1 rock standards have been used (PEKDEGER et al 1992; Tab. 1).

The statistical parameter of these determined major and trace elements in the volcanic rocks of the Gölcük area are presented in Tab. 1. Moreover, we refer to ÖZGÜR et al. (1990) and PEKDEGER et al. (1992) due to REE analyses and their interpretations additionally.

| | Trachyandesite | | | | | | | Trachyte | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | range | min | max | $\bar{x}$ | δ | m | n | range | min | max | $\bar{x}$ | δ | m |
| SiO2 % | 11 | 6.29 | 50.63 | 56.92 | 53.71 | 2.20 | 52.73 | 11 | 6.35 | 59.64 | 65.99 | 63.17 | 2.35 | 63.16 |
| Al2O3 % | 11 | 2.72 | 15.33 | 18.05 | 16.62 | 0.83 | 16.23 | 11 | 2.95 | 16.05 | 19.00 | 17.18 | 0.92 | 16.88 |
| Fe2O3 % | 11 | 1.35 | 5.09 | 6.44 | 5.93 | 0.48 | 5.95 | 11 | 3.57 | 1.16 | 4.73 | 2.98 | 1.02 | 2.55 |
| MgO % | 11 | 2.72 | 2.44 | 5.16 | 3.70 | 0.79 | 3.40 | 11 | 2.05 | 0.34 | 2.39 | 1.27 | 0.70 | 1.06 |
| CaO % | 11 | 3.90 | 5.43 | 9.33 | 6.97 | 1.26 | 6.69 | 11 | 2.81 | 1.65 | 4.46 | 2.89 | 1.04 | 2.81 |
| Na2O % | 11 | 3.12 | 2.83 | 5.95 | 3.64 | 0.92 | 3.17 | 11 | 2.13 | 4.39 | 6.52 | 5.29 | 0.59 | 5.34 |
| K2O % | 11 | 3.36 | 2.41 | 5.77 | 4.61 | 1.11 | 4.88 | 11 | 2.63 | 4.03 | 6.66 | 5.32 | 0.74 | 5.30 |
| TiO2 % | 29 | 1.85 | 0.40 | 2.25 | 0.88 | 0.40 | 0.77 | 29 | 1.04 | 0.26 | 1.30 | 0.59 | 0.22 | 0.53 |
| MnO % | 29 | 0.10 | 0.01 | 0.11 | 0.06 | 0.03 | 0.06 | 29 | 0.09 | 0.01 | 0.10 | 0.04 | 0.03 | 0.04 |
| P2O5 % | 11 | 0.43 | 0.44 | 0.87 | 0.68 | 0.14 | 0.68 | 11 | 0.29 | 0.06 | 0.35 | 0.22 | 0.09 | 0.23 |
| F ppm | 29 | 2960 | 240 | 3200 | 1415 | 699 | 1358 | 29 | 2275 | 150 | 2425 | 993 | 555 | 895 |
| V ppm | 11 | 65 | 106 | 171 | 135 | 20 | 127 | 11 | 50 | 30 | 88 | 58 | 21 | 50 |
| Cr ppm | 28 | 398 | 10 | 408 | 98 | 106 | 55 | 29 | 244 | 6 | 250 | 36 | 44 | 25 |
| Co ppm | 8 | 31 | 9 | 40 | 19 | 9 | 17 | 8 | 48 | 1 | 49 | 15 | 17 | 9 |
| Ni ppm | 29 | 182 | 4 | 186 | 46 | 46 | 30 | 29 | 232 | 2 | 234 | 32 | 43 | 22 |
| Cu ppm | 29 | 79 | 1 | 80 | 36 | 21 | 35 | 29 | 63 | 4 | 67 | 23 | 15 | 18 |
| Zn ppm | 29 | 954 | 42 | 996 | 120 | 171 | 87 | 29 | 98 | .23 | 121 | 66 | 24 | 65 |
| Rb ppm | 11 | 134 | 79 | 213 | 130 | 35 | 126 | 11 | 106 | 101 | 207 | 146 | 32 | 138 |
| Sr ppm | 11 | 2800 | 3000 | 5800 | 4427 | 987 | 4200 | 11 | 3200 | 1200 | 4400 | 2718 | 944 | 2600 |
| Zr ppm | 11 | 186 | 268 | 454 | 377 | 53 | 360 | 11 | 400 | 220 | 620 | 334 | 107 | 289 |
| Ba ppm | 11 | 1300 | 2300 | 3600 | 3045 | 468 | 3000 | 11 | 1600 | 900 | 2500 | 2018 | 431 | 2000 |
| Pb ppm | 8 | 429 | 1 | 430 | 49 | 79 | 34 | 11 | 244 | 6 | 250 | 55 | 51 | 32 |
| Th ppm | 11 | 61 | 35 | 96 | 52 | 16 | 47 | 11 | 65 | 29 | 94 | 50 | 18 | 41 |
| | Tephriphonolite | | | | | | | Pyroclastic series | | | | | | |
| SiO2 % | 5 | 2.69 | 50.86 | 53.55 | 52.30 | 0.96 | 52.16 | 23 | 13.86 | 52.54 | 66.40 | 57.76 | 3.63 | 57.45 |
| Al2O3 % | 5 | 1.65 | 15.56 | 17.21 | 16.48 | 0.63 | 16.18 | 23 | 4.30 | 14.80 | 19.10 | 16.52 | 0.93 | 16.23 |
| Fe2O3 % | 5 | 1.08 | 5.56 | 6.64 | 6.27 | 0.41 | 6.34 | 23 | 5.39 | 1.57 | 8.96 | 4.40 | 1.20 | 4.15 |
| MgO % | 5 | 0.98 | 3.06 | 4.04 | 3.39 | 0.44 | 3.06 | 23 | 4.73 | 0.15 | 4.88 | 2.20 | 0.96 | 2.12 |
| CaO % | 5 | 1.61 | 6.71 | 8.32 | 7.35 | 0.78 | 6.78 | 23 | 8.02 | 0.57 | 8.59 | 4.49 | 1.95 | 4.50 |
| Na2O % | 5 | 1.29 | 3.85 | 5.14 | 4.67 | 0.49 | 4.73 | 23 | 4.56 | 1.11 | 5.67 | 3.97 | 0.94 | 3.97 |
| K2O % | 5 | 0.61 | 5.37 | 5.98 | 5.65 | 0.26 | 5.41 | 23 | 6.92 | 3.94 | 10.86 | 5.58 | 1.31 | 5.41 |
| TiO2 % | 15 | 1.17 | 0.70 | 1.87 | 0.91 | 0.28 | 0.81 | 67 | 1.27 | 0.05 | 1.32 | 0.59 | 0.20 | 0.57 |
| MnO % | 15 | 0.10 | 0.06 | 0.16 | 0.09 | 0.03 | 0.08 | 67 | 2.94 | 0.01 | 2.94 | 0.11 | 0.35 | 0.07 |
| P2O5 % | 5 | 0.47 | 0.58 | 1.05 | 0.76 | 0.18 | 0.67 | 23 | 0.70 | 0.05 | 0.75 | 0.39 | 0.19 | 0.38 |
| F ppm | 15 | 562 | 1258 | 1820 | 1619 | 157 | 1635 | 66 | 2317 | 33 | 2650 | 1030 | 484 | 972 |
| V ppm | 5 | 61 | 113 | 174 | 135 | 25 | 116 | 23 | 140 | 20 | 160 | 85 | 40 | 78 |
| Cr ppm | 15 | 330 | 10 | 340 | 53 | 81 | 25 | 67 | 284 | 6 | 290 | 51 | 43 | 40 |
| Co ppm | 4 | 16 | 10 | 26 | 19 | 8 | 21 | 18 | 66 | 1 | 67 | 24 | 20 | 13 |
| Ni ppm | 15 | 56 | 10 | 66 | 24 | 15 | 18 | 67 | 174 | 4 | 178 | 37 | 36 | 28 |
| Cu ppm | 15 | 78 | 20 | 98 | 63 | 21 | 64 | 67 | 296 | 5 | 301 | 46 | 39 | 40 |
| Zn ppm | 15 | 70 | 86 | 156 | 106 | 20 | 97 | 67 | 249 | 16 | 265 | 96 | 43 | 83 |
| Rb ppm | 5 | 22 | 98 | 120 | 111 | 11 | 99 | 23 | 170 | 94 | 264 | 164 | 35 | 163 |
| Sr ppm | 5 | 1500 | 4700 | 6200 | 5860 | 654 | 6000 | 23 | 6400 | 200 | 6600 | 4048 | 1582 | 4300 |
| Zr ppm | 5 | 253 | 382 | 535 | 462 | 70 | 405 | 23 | 524 | 74 | 598 | 384 | 97 | 367 |
| Ba ppm | 5 | 800 | 2800 | 3600 | 3380 | 335 | 3400 | 23 | 4000 | 500 | 4500 | 2830 | 1000 | 2900 |
| Pb ppm | 15 | 60 | 2 | 62 | 35 | 16 | 29 | 67 | 465 | 5 | 470 | 68 | 70 | 52 |
| Th ppm | 5 | 91 | 6 | 97 | 55 | 33 | 48 | 22 | 79 | 18 | 97 | 62 | 16 | 62 |



Tab. 1: Statistical parameter of the major and trace elements in various volcanic rocks of the Gölcük area. For locations see PEKDEGER et al. (1992). n: number of samples; $\bar{x}$: mean; δ: standard deviation; m: median.

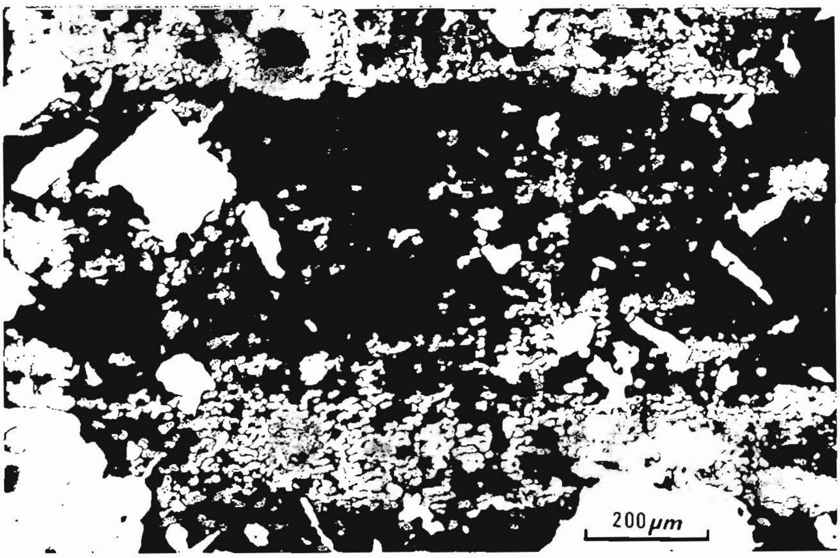


Fig. 3: Idiomorphic fluorapatite crystal in the basic tephriphonolite. Crossed nicols.

## PETROCHEMISTRY OF VOLCANIC ROCKS

The volcanic lava flows as well as the pyroclastic series indicate an Na-alkaline affinity (ÖZGÜR et al. 1990; PEKDEGER et al. 1992) which plays an important role for the high fluorine contents in the aqueous systems. The diagram (Fig. 4a) shows that the major element oxides $TiO_2$ and $Fe_2O_3$ (as total FeO) versus $SiO_2$ exhibit a negative correlation whereas $Al_2O_3$ represents a rough positive correlation. In Fig. 4b, MnO, MgO, and CaO display a negative correlation with $SiO_2$. $NA_2O$, $K_2O$, Ba, and Sr versus $SiO_2$ show variations which are identical with the magmatic differentiation process (Figs. 5a, b). This assumption establish that the volcanic activity is caused by a magmatic differentiation obviously. On the other hand, F and $P_2O_5$ versus $SiO_2$ in the same diagrams indicate a depletion from basic towards the acidic rocks and distinguish by a negative correlation which is contradictory to a common magmatic differentiation.

## FLUORINE IN VOLCANIC ROCKS

Generally, the volcanic rocks differ by their high F-contents from the sedimentary rocks. They have fluorine contents in a range of 30 to 3200 ppm and a background value of 1000 ppm (Fig. 6). Due to their rare occurrence, the pyroxenitic xenoliths with their unusually high F-contents ranging from 1710 to 6750 ppm are without relevance for hydrogeochemical problems (ÖZGÜR et al. 1990; PEKDEGER et al. 1992). These high fluorine contents in the basic pyroxenites depend upon the intensity of the mineral phase of fluorapatite, as observed microscopically (PEKDEGER et al. 1992).

F-contents in tephriphonolite (volcanic stage i) range from 1260 to 1820 ppm and indicate a mean value of 1635 ppm, which is identical with a range of the alkaline phonolite of the African rift systems (Kokubu 1956). They can be linked to the mineral phases of fluorapatite, biotite, hornblende, and pyroxene. The pyroclastic series (volcanic stage ii) have F-contents in a range of 30 to 2650 ppm and a background value of 1030 ppm. This background value is generally

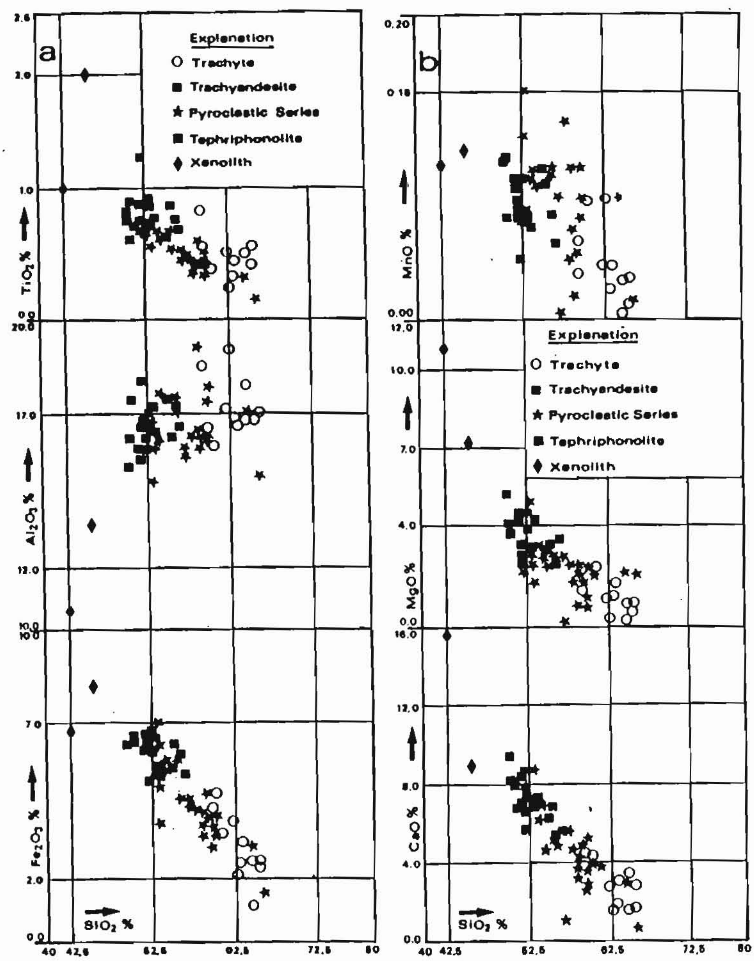


Fig. 4: Plot of $SiO_2$ versus $TiO_2$, $Al_2O_3$, and $Fe_2O_3$ (a) as well as MnO, MgO, and F (b) in the Gölcük volcanic rocks

identical with the mean value of 1000 ppm of the alkaline pyroclastics (KOKUBU 1956). The F-bearing minerals in the pyroclastic series are F-apatite, biotite, hornblende, pyroxene, fluorite, and glassy groundmass. In comparison to other volcanic rocks, an important portion of fluorine in the pyroclastic series may also be attributed to the glassy groundmass (FLÜHLER et al. 1982), because these rocks contain up to 90 % glassy groundmass.

During F-contents in trachyandesite (volcanic stage iii) distinguish by a range of 240 to 3200 ppm and a background value of 1415 ppm trachyte (volcanic stage iii) show fluorine contents in a range of 150 to 2425 ppm and a background value of 933 ppm. These high F-contents can be attributed to the various mineral phases, i.e. F-apatite, biotite, hornblende, and pyroxene.

Generally, there is a close correlation between F and $P_2O_5$ in the volcanic rocks which could indicate the geochemical role of fluorapatite as one of the important F-carriers (Fig. 7). Furthermore, this diagram displays a depletion of fluorine from basic toward the acidic rocks as a novelty of our investigations which is [illegible] process. It might be interpreted by an increasing discharge of fluorine during fumarolic stages subsequent to the volcanic eruptions indicating a degassing of an open system.

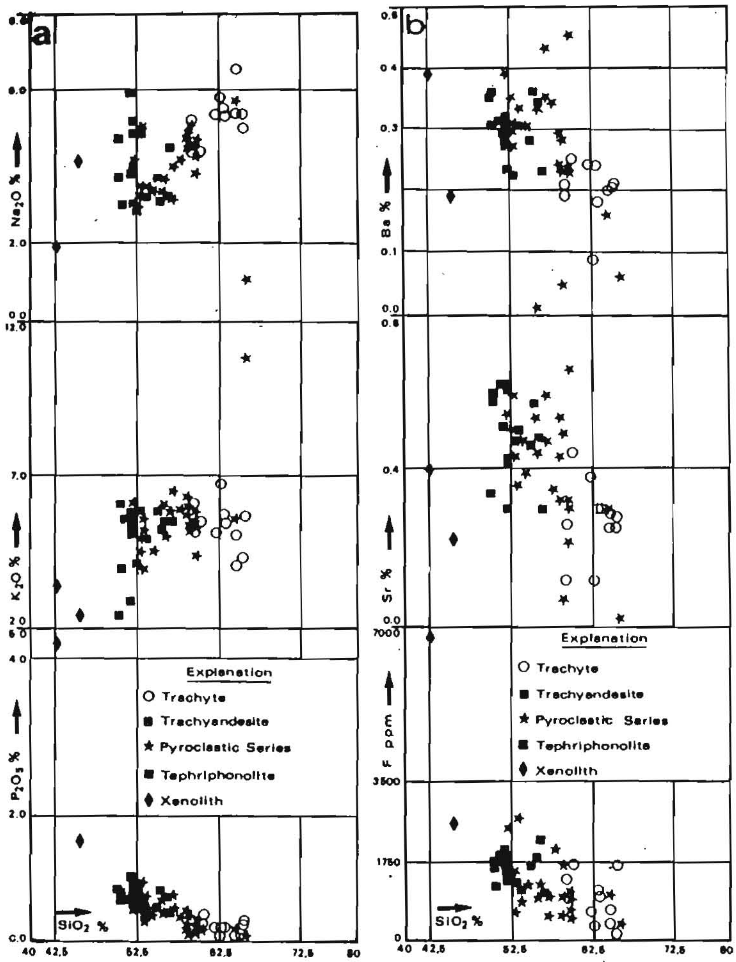


Fig. 5: Plot of $SiO_2$ versus $Na_2O$, $K_2O$, and $P_2O_5$ (a) as well as Ba, Sr, and F (b) in the Gölcük volcanic rocks

Moreover, the volcanic rocks are distinguished by extremely high REE contents with a maximum of 0.15 % of REE which can be derived from the occurrence of F-apatite (ÖZGÜR et al. 1990; PEKDEGER et al. 1992). The remarkable similarity of the REE patterns of the volcanic rocks suggests a common petrogenic origin for the whole rock spectrum of the volcanic sequence (CAPALDI et al. 1972).

**PLIOCENE VOLCANISM**

The volcanic activity in the Gölcük area has been divided into three stages (ÖZGÜR et al. 1990; Fig. 8). The basic tephriphonolite emplaced in the area of Gölcük lake, and were accompanied by local eruptions like a ring dike (stage i). Subsequently, the tephriphonolite lavas have been strongly affected by volcanic gases and dust explosions around the center of Gölcük intensively which marks the start of the second volcanic stage (stage ii). Products of this stage are great masses of friable tuffs, ignimbrites, and pumice tuffs dominating the recent landscape which reveals a series of strong explosion forming the recent caldera. The coarse-grained pyroclastic components, like bombs and lapillis, consist of sedimentary rocks, basic xenoliths, and tephriphonolite. They contain neither trachyandesites nor trachytes. Isolated extrusions of trachyandesites and trachytes have taken place at various localities in the center and surrounding area of the Gölcük caldera (stage iii). They are preserved as vents, dikes, and volcanic domes proving that the trachytes are always the latest volcanic event.

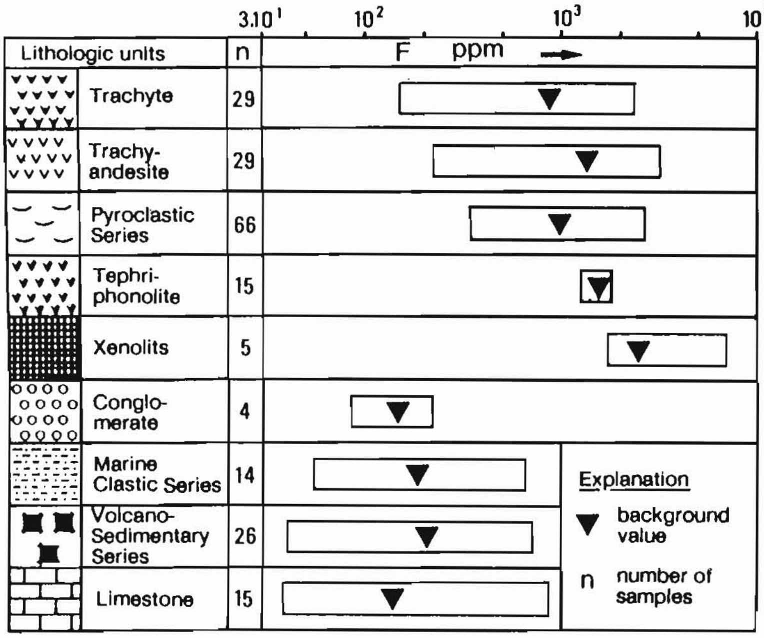


Fig. 6: Range and background values of fluorine in various volcanic rocks of the Gölcük area

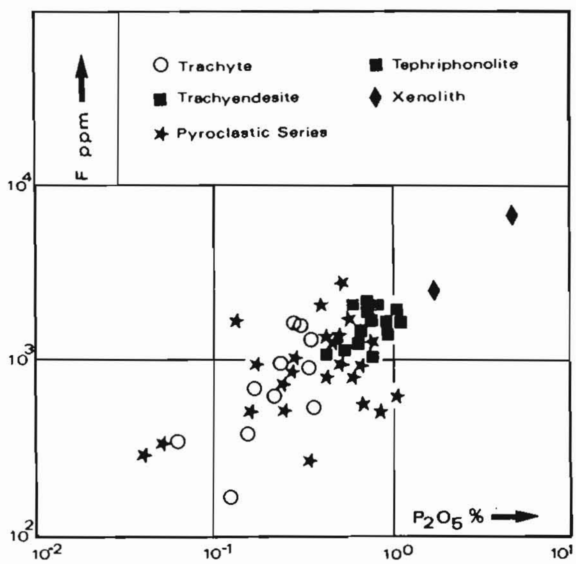


Fig. 7: Close correlation between F and $P_2O_5$ in various volcanic rocks of the Gölcük area

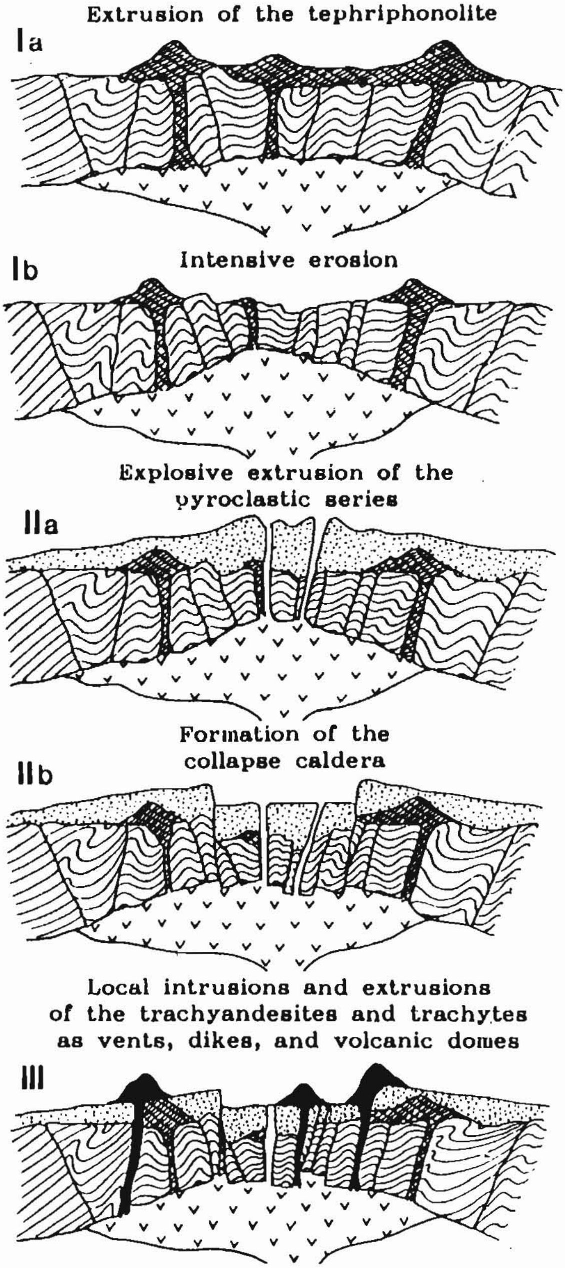


Fig. 8: Schematic record of the volcanic rocks in the Gölcük area. Not to scale.

## DISCUSSION AND CONCLUSIONS

The volcanic activity in central Anatolia seems to have developed in relation to the plate tectonic evolution of this region. As a result of formation of the plate tectonic event which is connected with the Afro-Arabian plate being subducted under the Euro-Asiatic plate (DEWEY et al. 1973), the volcanism began at least as early Paleocene continuing to Quaternary consequently (INNOCENTI et al. 1975, 1982; ERCAN 1982).

The volcanic activity in the Gölcük area is of Pliocene age (LEFEVRE et al. 1983) and shows a Na-alkaline character (PEKDEGER et al. 1992). The volcanic rocks in the area are one of the youngest events in central Anatolia. The unambiguously origin of the volcanic rocks and of the metamorphic overprinted xenoliths as deep-seated rocks is debatable, it will be reported by detailed investigations of $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ in a separate paper. The pyroxenitic xenoliths originate probably from the fragments of the oceanic crust which have been taken place in the time of ophiolitic activity.

In the Gölcük area, the volcanics start with the basic tephriphonolite lavas (stage i), succeeded by the pyroclastic series represented by friable tuff, ignimbrite, and pumice tuff (stage ii), and finally ending with trachyandesite and trachyte (stage iii).

The volcanic rocks in the area are characterized by high fluorine contents. They can be attributed to different mineral phases as essential F-carrier, i.e. F-apatite, biotite, hornblende, fluorite, and glassy groundmass. Moreover, the mineral phase pyroxene can contain F-contents ranging from 100 to 340 ppm (KOKUBU 1956; GREEN 1982). F-apatite is also an ubiquitous mineral. F versus $P_2O_5$ displays a close correlation which shows remarkable relative depletion of fluorine contents from the basic towards the acidic volcanic rocks as a novelty of this investigation. It can be interpreted that an important portion of F might be discharged during fumarolic activity and through interaction of hydrothermal water with the volcanic rocks. Furthermore, the small variability of the REE patterns indicates a close petrogenic relationship of the different volcanic stages (ÖZGÜR et al. 1990). They are differentiation products of a common magma chamber.

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## REFERENCES

CAPALDI, G., GASPARINI, P., MOAURA, A., SALVIA, E, and TRAVAGLIONE, O. (1972). Rare earth abundances in the alkaline rocks from Campania. Earth Planet Sci. Lett. 17, 247-257.

DEWEY, J.F., PITMAN, W.C., RYAN, W.B.F., and BONNIN, J. (1973). Plate tectonics and the evolution of alpine system. Bull.Geol.Soc.Am. 84, 3137-3180.

DULSKI, P. and MÖLLER, P. (1975). Neutronenaktivierungs-Spektrometrie und Neutronenaktivierungsanalyse in der geochemischen Analytik. Berlin, Hahn-Meitner-Inst. Kernforsch., Berlin GmbH, rept. HMI-B 117, 117 p.

ERCAN, T. (1986). Cenozoic volcanism in central Anatolia. Maden Tetkik ve Arama Enstitüsü Bull. 107, 119-140 (in Turkish).

FLÜHLER, H., POLOMSKI, J., and BLASER, P. (1982). Retention and movement of fluoride in soils. J. Environ. Qual. 11/3, 461-468.

GREEN, N. L. (1982). Fluorine geochemistry of Quaternary volcanic rocks from southwestern British Columbia: Some petrogenic implications. Contrib. Mineral. Petrol. 79, 405-410.

INNOCENTI, F., MAZZUOLI, R., PASQUARE, G., RADICATI DI BROZOLO, F., and VILLARI, L. (1975). The Neogene calkalkaline volcanism of central Anatolia: Geochronological data of Kayseri-Nigde area. Geol. Mag. 112(4), 349-360.

INNOCENTI, F., MANETTI, P., MAZZUOLI, R., PASQUARE, G., and VILLARI, L. (1982). Anatolia and northwestern Iran. in: Thorpe, R.S. (ed.), Andesites, 327-349, John Wiles & Sons.

KISSEL, C., LAJ, C., MAZAUD, A., POISSON, A., SAVASCIN, Y., SIMEKIS, K., FRAISSINET, C., and MERCIER, J.L. (1989). Paleomagnetic study of the Neogene formations of the Aegean area. in: Sengör, A.M.C. (ed.), Tectonic evolution of the Tethyan region, Nato, ASI Series C, Mathematical and Physical Series 259, 137-157.

KOKUBU, N. (1956). Fluorine in rocks. Geol. Fac. Sc., Kyushu univ., Series C, Vol. 2, No. 3, 95-149.

LEFEVRE, C., BELLON, M., and POISSON, A. (1983). Leucitites dans le volcanisme Pliocene de la region d'Isparta, Taurides occidentales, Turquie, C.R. Acad. Sc. Paris: 297(11), 367-372.

LE MAITRE, R.W. (1984). A proposal by the IUGS subcommission on the systematics of igneous rocks for a chemical classification of volcanic rocks based on the total alkali silica (TAS) diagram. Australian Journal of Earth Sciences 31, 243-255.

ÖZGÜR, N., PEKDEGER, A., SCHNEIDER, H.-J., and BILGIN, A. (1990). Pliocene volcanism in the Gölcük area, Isparta/western Taurides. Proc. Internat. Earth Sc. Congress on the Aegean Regions, Izmir/Turkey, IESCA Publ. 2, Vol. II, 411-419.

PEKDEGER, A., ÖZGÜR, N., SCHNEIDER, H.-J., and BILGIN, A. (1992b). High fluorine contents in aqueous systems of the Gölcük lake drainage area, Isparta/western Taurides. Proc. Internat. Earth Sc. Congress on the Aegean Regions, Izmir/Turkey, IESCA Publ. 2, Vol. I, 160-170.

PEKDEGER, A., SCHNEIDER, H.-J., and ÖZGÜR, N. (1992). Zur Hydrogeochemie von Fluorid in Grundwässern und die Gesteinsgeochemie in der Provinz Isparta/Türkei. DFG-Forschungsbericht, Freie Universität Berlin (in prep.).

POISSON, A., AKAY, E., DUMONT, J.F., and UYSAL, S. (1984). The Isparta angle: a Mesozoic paleorift in the western Taurides. in: Tekeli, O. and Göncüoglu, M.C. (eds.), Geology of Taurus belt, 11-26, Ankara.