ARISTOTLE UNIVERSITY OF THESSALONIKI
FACULTY OF ENGINEERING
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
SECTOR OF ELECTRICAL ENERGY
NUCLEAR TECHNOLOGY LABORATORY

Geological Analysis of Radon Exhalation on Cephalonia Island Based on In Situ Measurements

Ioannis Kaissas, Panagiotis Markoulatos

Cephalonia Island: Geological Framework

- Cephalonia is located in the Ionian Sea of western Greece and belongs to the External Hellenides
- The island is affected by the Cephalonia Transform Fault Zone (CTFZ), one of the major active structures of western Greece
- It lies close to the transition between the Paxos (Pre-Apulian) and Ionian Zones, which explains the strong lithological variability
- The mapped framework includes carbonate formations, localized flysch deposits and Quaternary to unconsolidated sediments
- Carbonates may enhance gas migration where karstification and connected fractures increase secondary permeability
- Flysch and unconsolidated sediments may behave differently because of their contrasting permeability and soil texture
- The marked sites were used to relate measured soil radon exhalation to lithology, mapped fault proximity and local near-surface conditions

2. MEASUREMENT METHODS

• In situ measurements were carried out using an accumulation chamber named AlphaGUARD PQ2000 PRO radon monitor operating in diffusion mode.

• Sampling was carried out under fair-weather conditions and without strong wind, to minimize pressure disturbances and turbulence around the chamber.

• Prior to each measurement, loose vegetation, organic debris, and surface irregularities were removed from the selected site. The upper soil layer was prepared by a shallow 3–5 cm excavation.

• Radon concentration was recorded every 10 minutes during a two-hour accumulation period.

• Temperature, relative humidity and pressure were recorded as supporting field parameters.

• The fitted concentration–time slope was estimated using weighted linear regression.

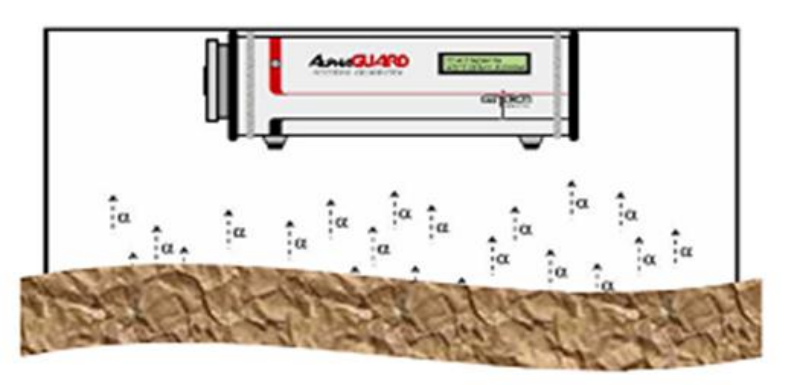
Exhalation-rate calculation

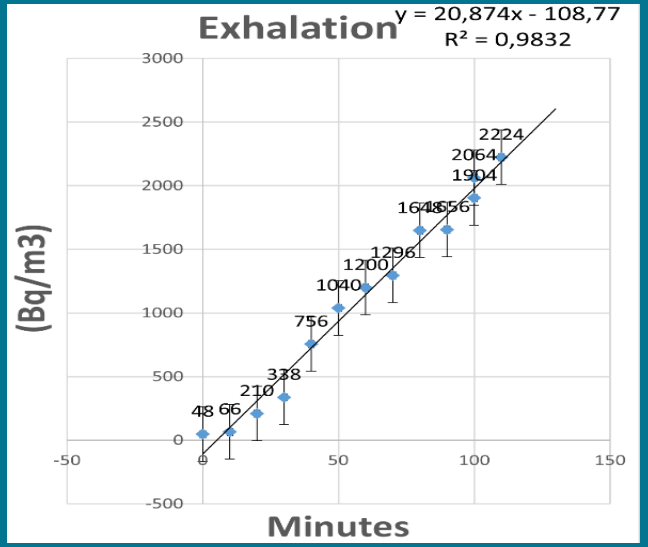
$E = (b \cdot V / A) \cdot 60$

b: fitted slope V: chamber volume A: covered surface
The factor 60 converts minute-based slopes to hourly units

Reporting

• Final values are presented as $E \pm \sigma E$ in Bq m^{-2} h^{-1}





Dataset Overview

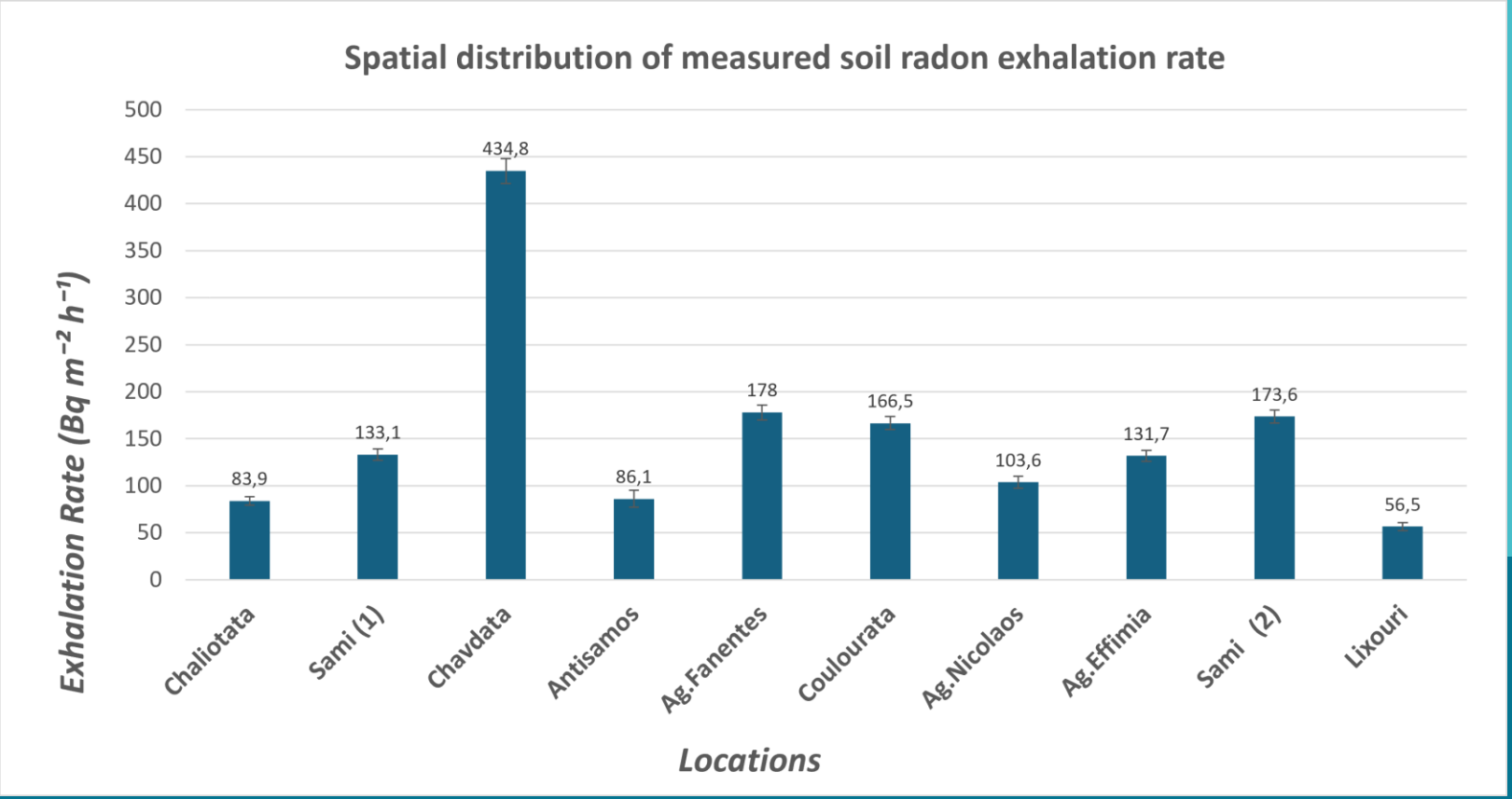
Location	Code	Nearest Fault distance	Lithological Background	E ± σE (Bq m⁻² h⁻¹)
Chaliotata	KEF001	850 m	Brecciated limestone	83.9 ± 4.5
Sami (1)	KEF002	111 m	Flysch formations	133.1 ± 6.2
Chavdata	KEF003	97 m	Calcarenites (sedim)	434.8 ± 13.2
Antisamos	KEF004	215 m	Thick-bedded limestone	86.1 ± 8.9
Agioi Fanentes	KEF005	55 m	Thick-bedded limestone	178.0 ± 8.0
Coulourata	KEF006	20 m	Flysch formations	166.5 ± 6.9
Agios Nikolaos	KEF007	222 m	Evaporitic brecciated limestone	103.6 ± 6.4
Agia Effimia	KEF008	838 m	Flysch formations	131.7 ± 5.7
Sami (2)	KEF009	111 m	Flysch formations	173.6 ± 7.0
Lixouri	KEF010	868 m	Sedimentary formations	56.5 ± 4.2

Range
- 56.5–434.8 Bq m⁻² h⁻¹

Highest value
- Chavdata: 434.8 ± 13.2 Bq m⁻² h⁻¹

Lowest value
- Lixouri: 56.5 ± 4.2 Bq m⁻² h⁻¹

Spatial Distribution of Soil Radon Exhalation



Measured exhalation rates with standard deviations, calculated with propagation method

Key observations

- Chavdata forms a clear high-value endpoint
- Lixouri defines the low-value endpoint
- Most of the other sites remain within about 80–180 Bq m^{-2} h^{-1}
- The spread shows that radon release is not uniform across the island

Lithological Background

Lithological group	Locations	n	Mean	Min	Max
Carbonate formations	Chaliotata; Chavdata; Antisamos; Agioi Fanentes; Agios Nikolaos	5	177.3	83.9	434.8
Flysch formations	Sami (1); Coulourata; Agia Effimia; Sami (2)	4	151.2	131.7	173.6
Sedimentary formations	Lixouri	1	56.5	56.5	56.5

Descriptive comparison according to dominant geological formation

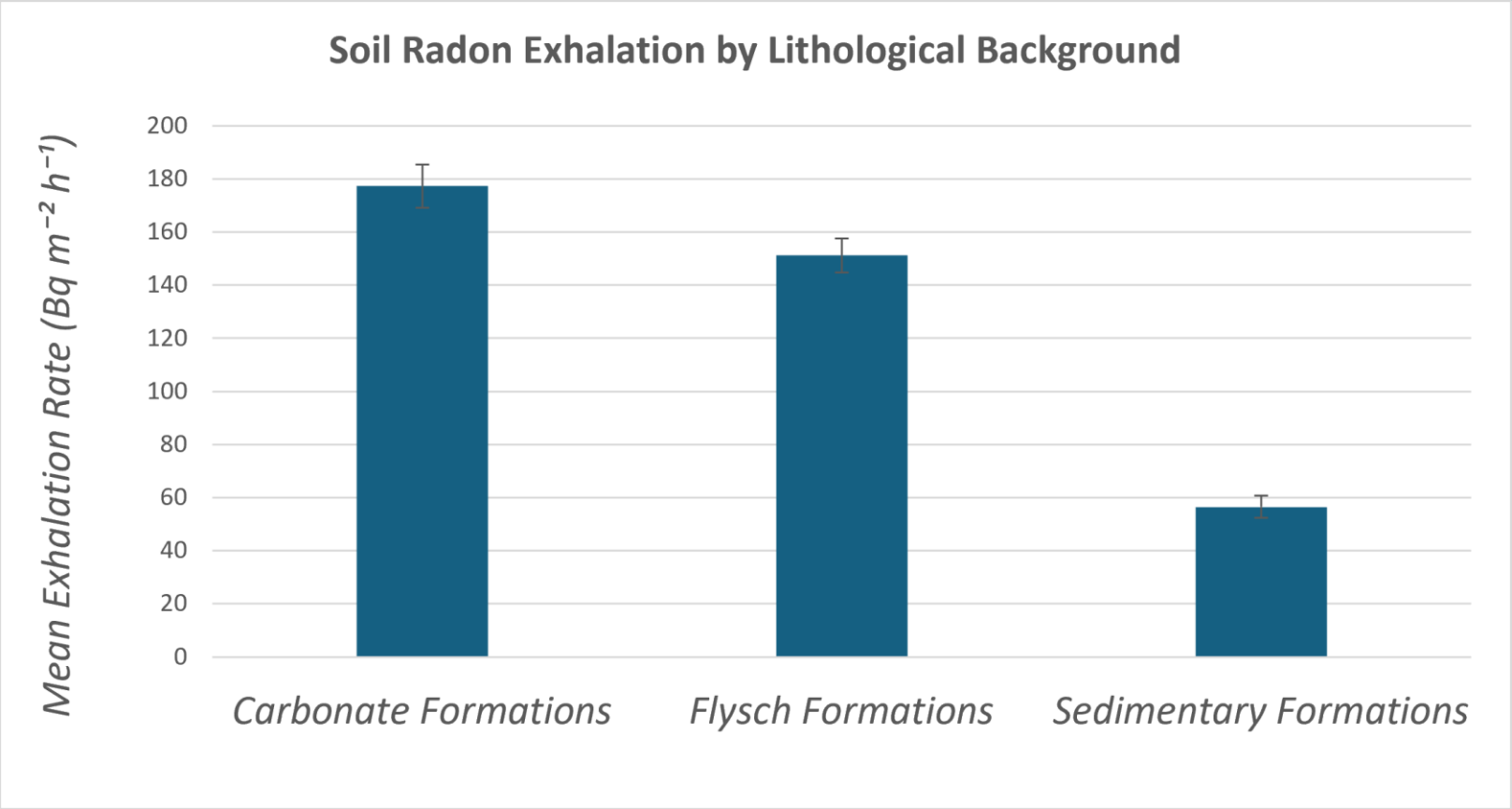
Carbonates
- Highest mean and widest range.
- The mean is strongly influenced by Chavdata

Flysch
- Moderate values.
- More compact internal interval

Sediments
- Represented by Lixouri.
- Defines the lowest measured flux

Mean Exhalation by Lithological Background

Grouped means used as descriptive geological comparison



Commentary

- Carbonates have the highest mean, mainly due to Chavdata
- The carbonate group also contains moderate values, so the spread is important
- Flysch remains intermediate and comparatively compact
- The sedimentary site gives the lowest value
- The graph is descriptive, not a fixed lithological ranking

Mapped Fault Structures: Distance Groups

Distance used as geological context, not deterministic control

Fault distance	Locations	n	Mean	Min	Max
<60 m	Coulourata, Agioi Fanentes	2	172.3	166.5	178.0
60–150 m	Sami (1), Sami (2), Chavdata	3	247.2	133.1	434.8
150–300 m	Antisamos, Agios Nikolaos	2	94.9	86.1	103.6
>800 m	Chaliotata, Lixouri, Agia Effimia	3	90.7	56.5	131.7

Observed pattern

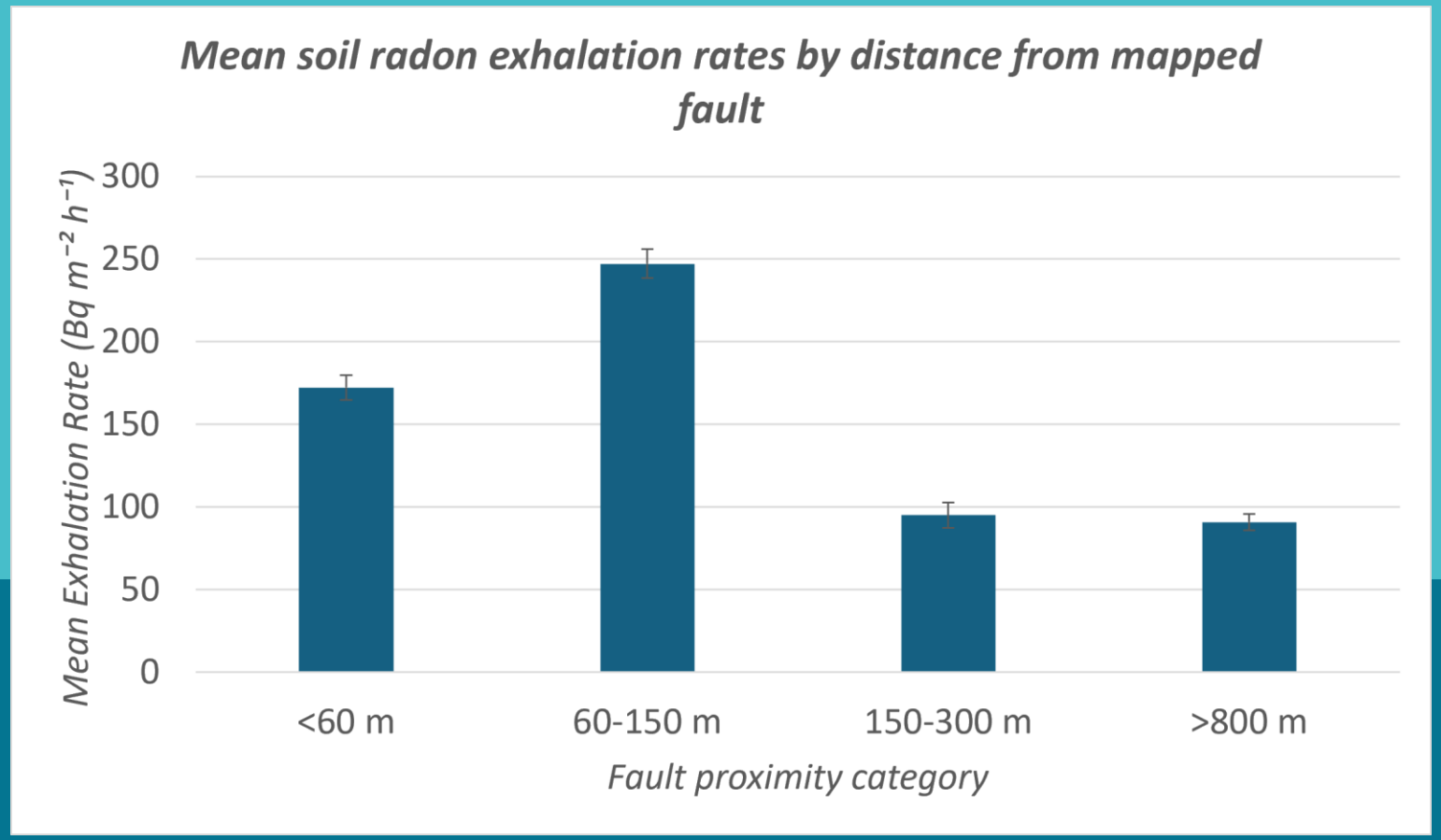
- The <60 m and 60–150 m groups have higher mean values than the more distant groups
- The 60–150 m mean is strongly affected by Chavdata
- More distant classes are lower and relatively compact

Geological reading

- Elevated values are compatible with fault-related deformation where connected fractures are present
- Distance alone does not represent permeability or source strength

Mean Exhalation by Fault-Distance Category

Descriptive relation to mapped fault structures



Commentary

- Closer categories are higher on average
- The trend should not be treated as deterministic
- Chavdata raises the 60–150 m group mean
- Fault proximity is useful geological context
- The main control remains the combination of structure, permeability and source availability

Regression Parameters and Internal Consistency

Weighted linear regression parameters for the retained accumulation curves

Location	R^2	Slope ± uncertainty	E ± σE	%
Chaliotata	0.959	8.911 ± 0.480	83.9 ± 4.5	5.4%
Sami (1)	0.946	14.127 ± 0.660	133.1 ± 6.2	4.7%
Chavdata	0.816	46.163 ± 1.406	434.8 ± 13.2	3.0%
Antisamos	0.760	9.136 ± 0.944	86.1 ± 8.9	10.3%
Agioi Fanentes	0.974	18.902 ± 0.851	178.0 ± 8.0	4.5%
Coulourata	0.908	17.680 ± 0.731	166.5 ± 6.9	4.1%
Agios Nikolaos	0.902	11.004 ± 0.676	103.6 ± 6.4	6.1%
Agia Effimia	0.945	13.987 ± 0.609	131.7 ± 5.7	4.4%
Sami (2)	0.947	18.429 ± 0.748	173.6 ± 7.0	4.1%
Lixouri	0.860	6.004 ± 0.444	56.5 ± 4.2	7.4%

Reliability check

- All retained measurements satisfy $R^2 > 0.6$. Seven curves exceed $R^2 = 0.90$
- Relative uncertainty ranges from 3.0% to 10.3%, supporting internal consistency
- Antisamos has the highest relative uncertainty, but remains within the accepted criterion

Integrated Interpretation and Conference Takeaways

Final synthesis of the updated Cephalonia dataset

Measured pattern

- E ranges from 56.5 to 434.8 Bq m^{-2} h^{-1}
- Chavdata is the maximum; Lixouri is the minimum
- Most sites remain within about 80–180 Bq m^{-2} h^{-1}
- All retained curves satisfy $R^2 > 0.6$

Geological interpretation

- Carbonates show the widest range, mainly because of Chavdata
- Flysch values are intermediate and compact
- Sediments show lower exhalation values
- Near-fault classes are higher on average, but distance is not a direct control
- Local permeability and fracture connectivity remain critical

Take-home message

- Cephalonia is not characterized by a uniform exhalation pattern; each location reflects its local geological setting
- Grouped comparisons organize the data, but the strongest conclusion is a multi-factor, site-specific response
- Dataset links in situ environmental radioactivity measurements with lithology, mapped fault structures and near-surface transport conditions

Integrated Interpretation and Conference Takeaways

- Cephalonia is not characterized by a uniform exhalation pattern; each location reflects its local geological setting.
- Grouped comparisons organize the data, but the strongest conclusion is a multi-factor, site-specific response.
- Dataset links in situ environmental radioactivity measurements with lithology, mapped fault structures and near-surface transport conditions on Cephalonia.