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CONTAMINATION OF TERRESTRIAL GASTEROPDA IN A BIOTOPE WITH LOW-LEVEL α CONTAMINATION DUE TO PLUTONIUM AND URANIUM

[Contamination de gasteropodes terrestres habitant un biotope á bas niveau de contamination α due au plutonium et á l'uranium]

By

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THE CONTAMINATION OF TERRESTRIAL GASTEROPDA IN A BIOTOPE WITH LOW-LEVEL α CONTAMINATION DUE TO PLUTONIUM AND URANIUM

Summary

A study was made of the degree of contamination of the terrestrial gasteropoda: Leucocroa Candidissima Drap., Helix punctata Müll. and Helix pisana Müll. caused by the rupture of a thermonuclear bomb at Palomares (Almeria, Spain).

This contamination relates to the contamination of the plants on which they live, whether cultivated plants (corn, broad beans, tomatoes, cabbages, etc.), or wild plants typical of the subtropical climate of this zone(Lygeum spartum, Asparagus horidus, Passerina hirsuta, etc.). The degree of contamination of the different soil types was also specified. Radioactivity evaluated the first five centimeters depth of the first layer where the fixed radioactivity acts most easily and directly on the gasteropoda.

Finally, the relationships existing between soil, plant, and gasteropoda flesh and shell contamination was studied.

Introduction

There is no doubt that the researcher is fortunate to have available a natural biotope at a certain level of α contamination due to plutonium and uranium for studying its effects on the biocenosis.

These circumstances occurred in the village of Palomares (Almeria, Spain) (Figure 1), when on January 17, 1966 a B-52 and a tanker plane belonging to the U.S. Air Force collided during in-flight fueling. The debris scattered over a vast extent of the village and its vicinity.

Because of the rupture of two of the bombs it was carrying a plutonium and uranium aerosol contaminated a zone of about 226 hectares, which was rapidly decontaminated. The highly contaminated earth was transported to the United States and put into a disposal facility for radioactive residue.

Some of the soil, still contaminated to a certain degree due to these α emitters, made it possible for us to study the behavior of a few living creatures. In the present communication we are presenting the information we obtained from terrestrial gastropoda living in this region. We were able to collect quantities (18 batches of more than half a kilogram) of the species *Helix pisana Müll.*, *Helix punctata Müll.*, and *Leucocera condidissima Drap.*, on several occasions from 1966 to 1969, sufficient to establish a relationship between the plant behavior and soils of the region.

Characteristics of the sampling zones

Around Palomares, a village of 1,200, 6 sampling zones were selected. Not far from there passes the Almanzora River, dry most of the year, but which in a few days can start overflowing because of the pluviometric conditions in this region with very irregularly distributed rainfall.

The climate is mild and calm like all subtropical, Mediterranean climates, with a luminous sky and an annual average temperature of 19°C.

The zone is bounded to the NE and NW by a mountainous system (Sierra de la Herreria and the Algarrobinas) of a rocky and abrupt appearance cleft by the gorges of mountain torrents. To the left of the village passes the dry bed of the Almanzora River. To the south the great rocky beach stretches in an arc from Punta del Rio to beyond Garrucha. Toward Vera the great cultivated expanses are typical of the region (tomatoes, corn, broad beans, alfalfa, barley, orange and lemon trees). Toward Garrucha is a semi-desert region. The wild vegetation is semi-tropical with palms, carob trees, pomegranates, olives, prickly pears, etc. [4, 5].

Within the framework of the subtropical climate we can observe several clear micro-climates represented by:

Salicornicta: with typical Salicornia fruticosa, Arthrocnemum macrostachya, Suaeda fructicosa, Atriplex roseum, and Salsola kali.

Cakiletea maritimae: where we found Cakile maritima and Polygomum maritimum.

Neriotamaricetea: with Tamarix gallica, Tamarix africana and Merium oleander.

Quercetea-Ilices: with *Alianza Oleoceratonion*, with Olea europaca and Chamaerops humilis.

Location of the sampling zones

Two imaginary lines were drawn to pass on each side of the main population center of Palomares village which is not what one might properly call an urban center given its irregular distribution; groups of houses or separate houses do not form a street over a wide and topographically irregular surface, crossed by a road, paths, irrigation ditches, etc. (see Figure 2).

The zone is sparsely treed (pomegranate, carob, etc.) and the vicinity has some irrigated cultivation in valleys and low lying areas. The rest of the land corresponds to a desert landscape where sparse vegetation grows (*Nicotiana glauca, Cucumis prophetarum, Atriplex roseum*, prickly pear, palms, etc.).

The zone between these two lines was called zone-5. Within this and to the east we selected area 5-2. This area has hard, rocky and dry soil which, however, is cultivated with alfalfa, tomatoes and corn grown in rotation.

Beyond the west line of zone-5, we find zone-2. In this zone we have three sampling areas: area 2-1 near the village cemetary of Palomares, with the typical chalkey marls (with pyrite nodules) of the region, without the changes of the other areas which were cultivated and fertilized. Vegetation in the zone is strictly wild and corresponds to a halophilic phytocenosis (Passerina hirsuta, Asparagus horidus, Artemisia hispanica, Lygeum spartum, *Suaeda fructicosa, Arthrocnemum macrostachya,* Piptatherum miliaceum, *Salsola kali*).

Area 2-2 corresponds to a soil under cultivation even though it has very few appropriate qualities. In the season just past planting was not possible because this chalky soil was highly saline and alkaline from hard water.

Tomatoes, a few cabbages, broad beans, and a few fruit trees, particularly lemon and orange, were grown in this area.

Area 2-3B, selected as a control or reference point relative to the other areas in case of the existence of considerable contamination of the biocenosis, is far enough away from the Palomares zone to possibly eliminate any type of contamination due to the air accident. It is located near Kilometer 36 of the Vera to Aguilas road. The ground and vegetation are identical to point 2-1. In these chakly marls we also found pyrite nodules and fossilized remains of Ostreidae and Pectinidae.

Zone 3, approximately located between the bed of the Almanzora River and the east line of zone-5, is by and large a cultivated region, lower in altitude than the others and covered by an irregular layer of fine sand from Almanzora River floods.

Within this zone, areas 3-1 and 3-2, under cultivation of corn and barley, have similar characteristics.

Nature of the ground

The following values for certain ions [6], Ca^{++}, $SO_4^{=}$ and CO_3H^-, were evaluated by dissolving Palomares soil fractions in water: point 2-2 yielded the least Ca^{++} and $SO_4^{=}$; in comparison, point 3-2 gives us 10 times more sulfates and 7 times more calcium; point 5-2 doubles the quantites of the previous point, yielding, by comparison with 2-2, 15 times more calcium and 23 times more $SO_4^{=}$; point 3-1, exceeding even these values, contains 29 times more $SO_4^{=}$ and 19 times more Ca^{++} than the reference point. Finally, points 2-3B and 2-1 yield values which are practically the same and which are the highest of all zones, 39 times greater in $SO_4^{=}$ and 31 times in Ca^{++}.

Table I below summarizes this information.

I. Proportion of Ca^{++} and $SO_4^{=}$ in soils from different points in Palomares.

Point	Proportional values	
	Ca^{++}	$SO_4^{=}$
2-2	1	1
3-2	7	10
5-2	15	23
3-1	19	29
2-3B and 2-1	31	39

Bicarbonate values were practically the same in all of the areas.

Location of the various points within the sampling areas

All the areas except the control (2-3B) are in a 50 m sided square whose two 71 m diagonals were drawn and on which the various points, 9 in all, were separated from each other and the corners by 11.8 m. Numbering begins at the point nearest geographical north and continues on the same diagonal to point 5 which coincides with the point nearest the south. Point 6, onthe other diagonal, is closest to geographical east. The other points follow, number 9 coinciding with the position nearest to west. At the central point, the diagonals cross at point 3.

Area 5-2 does not adapt exactly to this model because of its terrain.

The general form of control area 2-3B corresponds to the same schema with a square 50 m on a side but only 5 points in all on the two diagonals. The two diagonals then cross at point 2 (see Figure 3).

Sampling methods

The first soil samples were taken on the points indicated and later a meter away to the north, south, east and west.

The plants were always collected from an area approximately 1 mm in diameter centered on each point.

The most typical and most frequently occurring plants were selected, particularly *Lygeum spartum* and *Passerina hirsuta* because snails were often found on their tufts.

We did not determine a relationship between snails and the points. Given their mobility we prefered to determine their relationship over the whole area.

Measurement of activity, methods

After noting the wet and dry weights of the shells and the rest of the animal we incinerated them.

An extraction method using an appropriate mixture of hydrofluoric and nitric acids was used on these ashes.

This same method measured soil and plant activity.

Measurement of activity, results

Soil at points 3-2 and 2-2 yield the highest contamination values, distantly followed by point 3-1 while the remaining 2-1 and 5-2 yield values similar to those of control point 2-3B.

It must be emphasized that these averages were obtained from many samples. In some cases, particularly at point 2-1, the values were so disparatly high they were no longer significant. This is due to the inhomogeneous distribution of the radioactive particles in spite of the operations designed to homogenize the plutonium and uranium particles scattered on the ground [6].

Plant contamination clearly does not concentrate the soil contaminating elements since its values are lower. Cultivated plants' contamination values are much lower than wild plants' values. This is clearly apparent for areas 2-2 and 3-2 where the values are several thousand times lower than those for the soils. The plants from points 3-1 and 5-2 are also more than a hundred times lower in activity than the soil in which they grow.

All the areas mentioned are under cultivation.

The areas with wild plants, 2-3B and 2-1, show a much higher external contamination in their vegetation. Dust settles abundantly on these plants since the climatic conditions lack sprayed water to clean them.

At first it seems strange that area 2-1, whose soil yields the lowest values, shows the highest plant contamination: approximately 100 times higher. This is explained by the inhomogeneous distribution of uranium and plutonium particles discussed above.

α activity in the soils of the Palomares (Almeria) region seems to be one of the highest in Spain in relation to other provinces and other types of soil [7].

α activity was determined by dividing samples into two parts, one washed first, the other directly treated. Generally, as there was reason to expect, the unwashed yielded higher values. The difference in values is the supplement due to external contamination [6, 7].

Below we give the information obtained from the soils and the vegetation (Table II-VIII).

By relating Palomares' plutonium and uranium α soil and plant contamination to the gasteropoda living there, we see that the latter are completely independent although they feed on these plants and function on the contaminated soil.

Gasteropod are contaminated least in their bodies and most in their shells. In area 5-2 we collected Helix pisana eggs in quantity on a single occasion. We interpret the high analyzed values as external contamination due to the soil since these animals lay their eggs in the ground. This hypothesis was reinforced by the information that their bodies yield activity values much higher than in the same species at other points. This is surely because part of their body is buried during egg laying and soil particles adhere to the mucous of their foot.

Appended are tables of the measurements of activity of the different parts of the gasteropods and the various areas (Table IX).

II. Measurements of α activity in soils from the Palomares contaminated area (from 0 to 5 centimeters in depth)

Areas	Pci/g
2-1	550.000×10^{-2}
2-2	$13,315.909 \times 10^{-2}$
2-3B	886.364×10^{-2}
3-1	$2,315.909 \times 10^{-2}$
3-2	$61,345.455 \times 10^{-2}$
5-2	513.636×10^{-2}

These activity averages were obtained with values found in the J.E.N. of Spain laboratories and in those of the L.A.N.L. of New Mexico, U.S.A. [6, 7].

III. Measurements of α activity in vegetation from the Palomares contaminated area

Area 2-3B

Point	Species' Latin name	Pci/g undried wt.
2-3B-3	Artemisia Lamk	2.769×10^{-2}
2-3B-4	Artemisia Lamk	0.109×10^{-2}
2-3B-5	Artemisia Lamk	1.072×10^{-2}
2-3B-4	Asparagus horidus L.	0.342×10^{-2}
2-3B-2	Lygeum spartum Loefl.	0.878×10^{-2}
2-3B-2	Passerina hirsuta L.	48.522×10^{-2}
2-3B-1	Suaeda fructicosa Forsk	0.270×10^{-2}
2-3B-3	Suaeda fructicosa Forsk	0.578×10^{-2}
2-3B-4	Suaeda fructicosa Forsk	1.640×10^{-2}
	average value	6.242×10^{-2}

IV. Measurements of α activity in the Palomares contaminated area

Area 2-1

Point	Species' Latin name	Pci/g un-dried wt.
2-1-7	Artemisa hispanica Lamk.	64.299×10^{-2}
2-1-8	Artemisa hispanica Lamk.	65.804×10^{-2}
2-1-9	Artemisa hispanica Lamk.	22.620×10^{-2}
2-1-3	Asparagus horidus L.	0.526×10^{-2}
2-1-4	Asparagus horidus L.	1.536×10^{-2}
2-1-5	Asparagus horidus L.	33.135×10^{-2}
2-1-1	Lygeum spartum Loefl.	67.545×10^{-2}
2-1-2	Lygeum spartum Loefl.	439.663×10^{-2}
2-1-6	Lygeum spartum Loefl.	34.837×10^{-2}
2-1-2	Passerina hirsuta L.	2.472×10^{-2}
2-1-3	Passerina hirsuta L.	105.700×10^{-2}
2-1-5	Passerina hirsuta L.	20.175×10^{-2}
2-1-6	Passerina hirsuta L.	2.038×10^{-2}
2-1-6	Piptatherum miliaceum (L) Coss.	192.520×10^{-2}
2-1-7	Piptatherum miliaceum (L) Coss.	52.272×10^{-2}
2-1-8	Piptatherum miliaceum (L) Coss.	1085.044×10^{-2}
2-1-2	Salsola sp. L.	0.458×10^{-2}
2-1-3	Salsola sp. L.	1.443×10^{-2}
2-1-5	Salsola sp. L.	1.481×10^{-2}
Average value (including Piptatherum miliaceum of point 2-1-8)		115.451×10^{-2}
Average value (excluding this plant)		61.585×10^{-2}

V. Measurements of α activity of vegetation in the Palomares contaminated area

Area 2-2

Point	Species' Latin name	Common name	Pci/g un-dried wt.
	Brassica oleracea L.	Cabbage	0.095×10^{-2}
	Citrus limonium Risso	Lemons (peeled)	0.002×10^{-2}
	Ficus carica L.	Fig tree (leaf)	7.764×10^{-2}
	Ficus carica L.	Figs (peeled)	0.017×10^{-2}
	Ficus carica L.	Skin of figs	0.020×10^{-2}
	Opuntia sp. Mill.	Prickly pear (plant)	23.315×10^{-2}
	Opuntia sp. Mill.	Prickly pear (fruit peeled)	0.015×10^{-2}
	Opuntia sp. Mill.	Prickly pear (fruit skins)	0.159×10^{-2}
	Punica granatum L.	Pomegranates (peeled)	0.009×10^{-2}
	Punica granatum L.	Pomegranate skins	0.003×10^{-2}
2-2-3	Solanum lycopersicum L.	Tomato plant (leaves)	0.386×10^{-2}
2-2-3	Solanum lycopersicum L.	Tomatoes	0.001×10^{-2}
2-2-4	Solanum lycopersicum L.	Tomatoes	0.002×10^{-2}
2-2-6	Solanum lycopersicum L.	Tomatoes	0.002×10^{-2}
2-2-7	Solanum lycopersicum L.	Tomatoes	0.002×10^{-2}
2-2-8	Solanum lycopersicum L.	Tomatoes	0.001×10^{-2}
2-2-9	Solanum lycopersicum L.	Tomatoes	0.061×10^{-2}
	Vicia faba L.	Broad beans	0.022×10^{-2}
	Average value		1.771×10^{-2}
	Average foliage value		0.241×10^{-2}

VI. Measurements of α activity in vegetation from the Palomares contaminated area

Area 5-2

Point	Species' Latin name	Common name	Pci/g un-dried wt.
5-2-8	Allium cepa L.	Onion with leaf	0.044×10^{-2}
5-2-1	Medicago sativa L.	Alfalfa	18.359×10^{-2}
5-2-2	Medicago sativa L.	Alfalfa	15.018×10^{-2}
5-2-3	Medicago sativa L.	Alfalfa	6.288×10^{-2}
5-2-4	Medicago sativa L.	Alfalfa	27.162×10^{-2}
5-2-5	Medicago sativa L.	Alfalfa	11.826×10^{-2}
5-2-7	Solanum lycopersicum L.	Tomato plant	2.097×10^{-2}
5-2-7	Solanum lycopersicum L.	Tomatoes	0.013×10^{-2}
5-2-8	Solanum lycopersicum L.	Tomato plant	0.760×10^{-2}
5-2-8	Solanum lycopersicum L.	Tomatoes	0.016×10^{-2}
5-2-9	Solanum lycopersicum L.	Tomatoes	0.004×10^{-2}
5-2-7	Vicia faba L.	Broad bean (plant)	0.133×10^{-2}
5-2-7	Vicia faba L.	Broad bean	0.007×10^{-2}
5-2-7	Vicia faba L.	Broad bean pod w/o beans	0.021×10^{-2}
5-2-7	Vicia faba L.	Pod w/beans	0.012×10^{-2}
5-2-8	Vicia faba L.	Broad bean (plant)	0.405×10^{-2}
5-2-8	Vicia faba L.	Broad bean	0.006×10^{-2}
5-2-8	Vicia faba L.	Broad bean pod w/o beans	0.271×10^{-2}
5-2-8	Vicia faba L.	Pod w/beans	0.013×10^{-2}
5-2-7	Zea mays L.	Corn plant	1.340×10^{-2}
5-2-7	Zea mays L.	Corn kernels	0.003×10^{-2}
5-2-8	Zea mays L.	Corn plant	0.532×10^{-2}
5-2-8	Zea mays L.	Corn kernels	0.014×10^{-2}
	Average value		3.667×10^{-2}
	Average foliage value		7.622×10^{-2}

VII. Measurements of α activity in vegetation from the Palomares contaminated area

Area 3-1

Point	Species' Latin name	Common name	pci/g un-dried wt.
	Zea mays L.	Corn plant	20.782×10^{-2}
	Zea mays L.	Kernel of corn	3.136×10^{-2}
	Average value		11.959×10^{-2}
	Average foliage value		20.782×10^{-2}

VIII. Measurements of α activity in vegetation from the Palomares contaminated area

Area 3-2

Point	Species' Latin name	Common name	pci/g un-dried wt.
3-2-4	Vicia faba L.	Broad bean plant	0.847×10^{-2}
3-2-4	Vicia faba L.	Broad bean	0.020×10^{-2}
3-2-4	Vicia faba L.	Broad bean pod w/o beans	0.036×10^{-2}
3-2-4	Vicia faba L.	Broad bean pod w/beans	0.026×10^{-2}
3-2-5	Vicia faba L.	Broad bean plant	0.513×10^{-2}
3-2-5	Vicia faba L.	Broad bean	0.006×10^{-2}
3-2-5	Vicia faba L.	Broad bean pod w/o beans	0.163×10^{-2}
3-2-5	Vicia faba L.	Broad bean pod w/beans	0.133×10^{-2}
3-2-6	Vicia faba L.	Broad bean plant	0.910×10^{-2}
3-2-6	Vicia faba L.	Broad bean	0.011×10^{-2}
3-2-6	Vicia faba L.	Broad bean pod w/o beans	0.410×10^{-2}
3-2-6	Vicia faba L.	Broad bean pod w/beans	0.080×10^{-2}
3-2-7	Vicia faba L.	Broad bean plant	0.300×10^{-2}
3-2-7	Vicia faba L.	Broad bean	0.004×10^{-2}
3-2-7	Vicia faba L.	Broad bean pod w/o beans	0.010×10^{-2}
3-2-7	Vicia faba L.	Broad bean pod w/beans	0.304×10^{-2}
3-2-1	Zea mays L.	Corn plant	0.177×10^{-2}
3-2-2	Zea mays L.	Corn plant	3.353×10^{-2}
3-2-2	Zea mays L.	Kernel of corn	31.976×10^{-2}
3-2-3	Zea mays L.	Corn plant	1.532×10^{-2}
3-2-8	Zea mays L.	Corn plant	0.048×10^{-2}
3-2-9	Zea mays L.	Corn plant	0.318×10^{-2}
3-2-9	Zea mays L.	Kernel of corn	0.013×10^{-2}
		Average value	1.879×10^{-2}
		Average foliage value	1.111×10^{-2}

IX. Measurements of α activity in gasteropods from the Palomares contaminated area

Species' Latin name	Soft parts (pci/g undried wt.)	Shells (pci/g undried wt.)
Area 2-1		
Helix pisana Müll	0.027	0.052
Leucocroa candidissima Darp	0.013	0.112
Average	0.20	0.82
Area 2-2		
Helix pisana Müll	0.006	0.103
Helix punctata Müll	0.016	0.050
Average	0.011	0.077
Area 2-3B		
Helix pisana Müll	0.007	0.044
Leucocroa candidissima Drap.	0.020	0.018
Average	0.014	0.031
Area 3-1		
Helix pisana Müll	0.016	0.075
Area 3-2		
Helix pisana Müll	0.011	0.032
Helix punctata Müll	0.019	0.035
Average	0.015	0.034

Species' Latin name	Eggs (pci/g undried wt.)	Soft parts (pci/g undried wt.)	Shells (pci/g undried wt.)
Helix pisana Müll	0.212	0.090	0.030

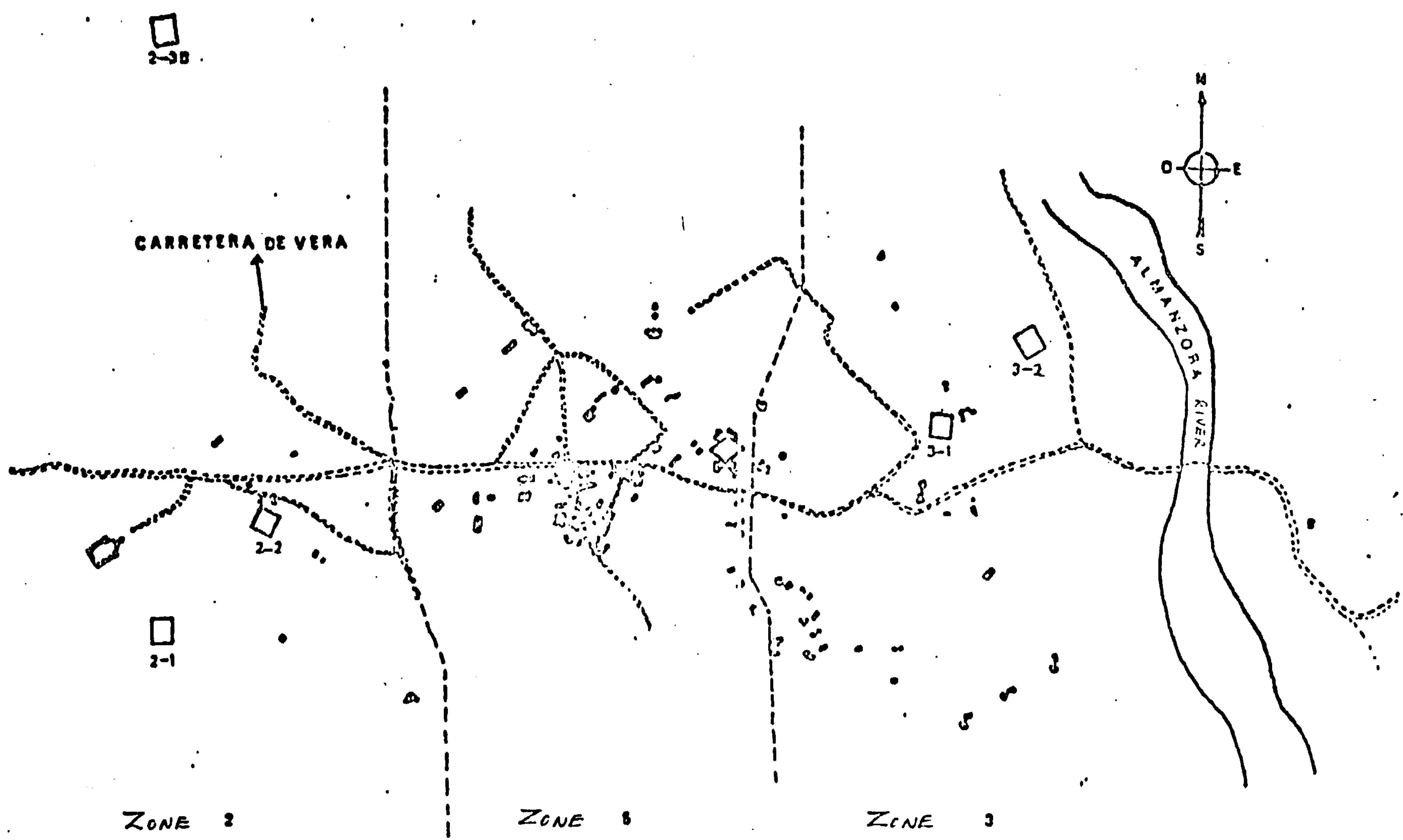

Figure 2. The village of Palomares.

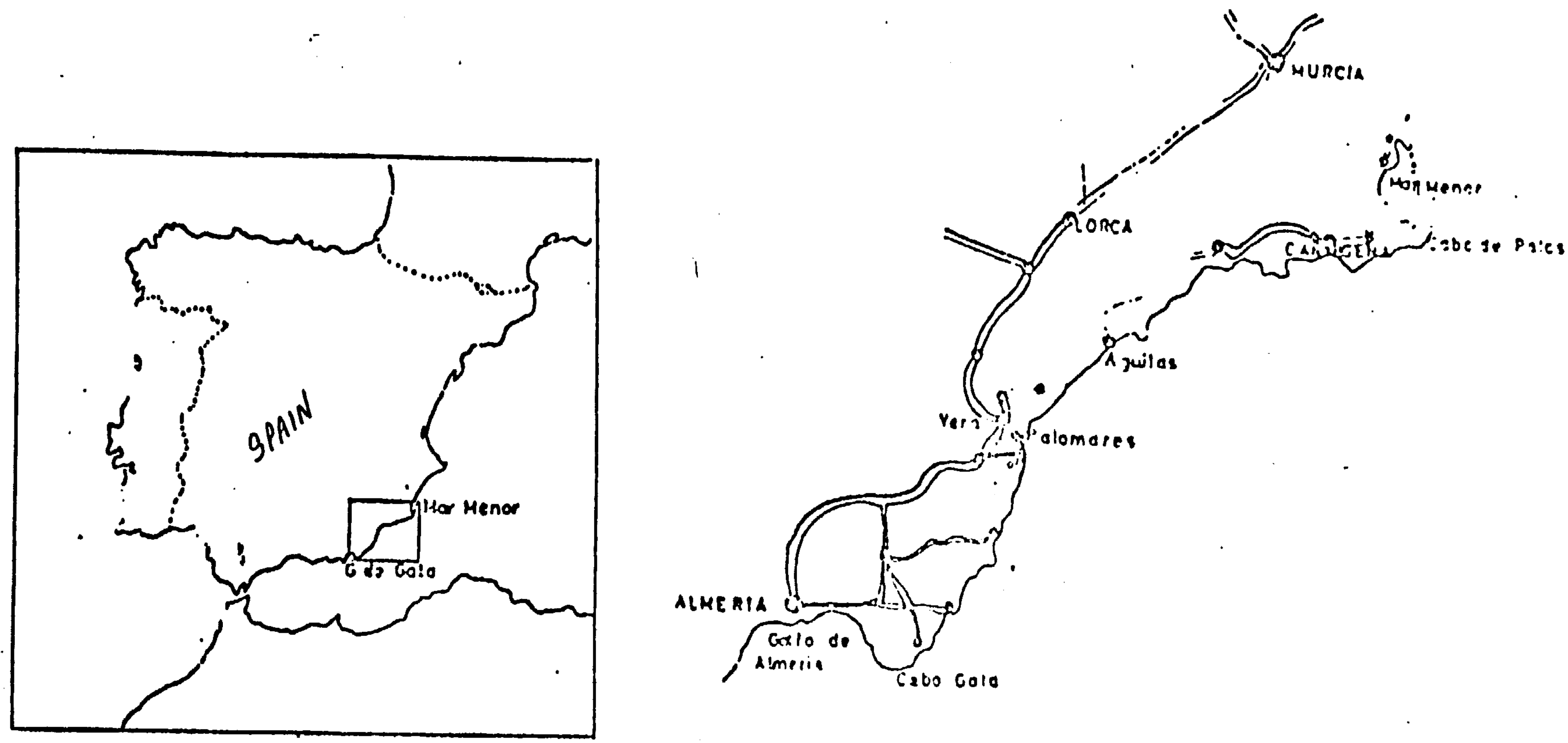

Figure 1. Location of the village of Palomares.

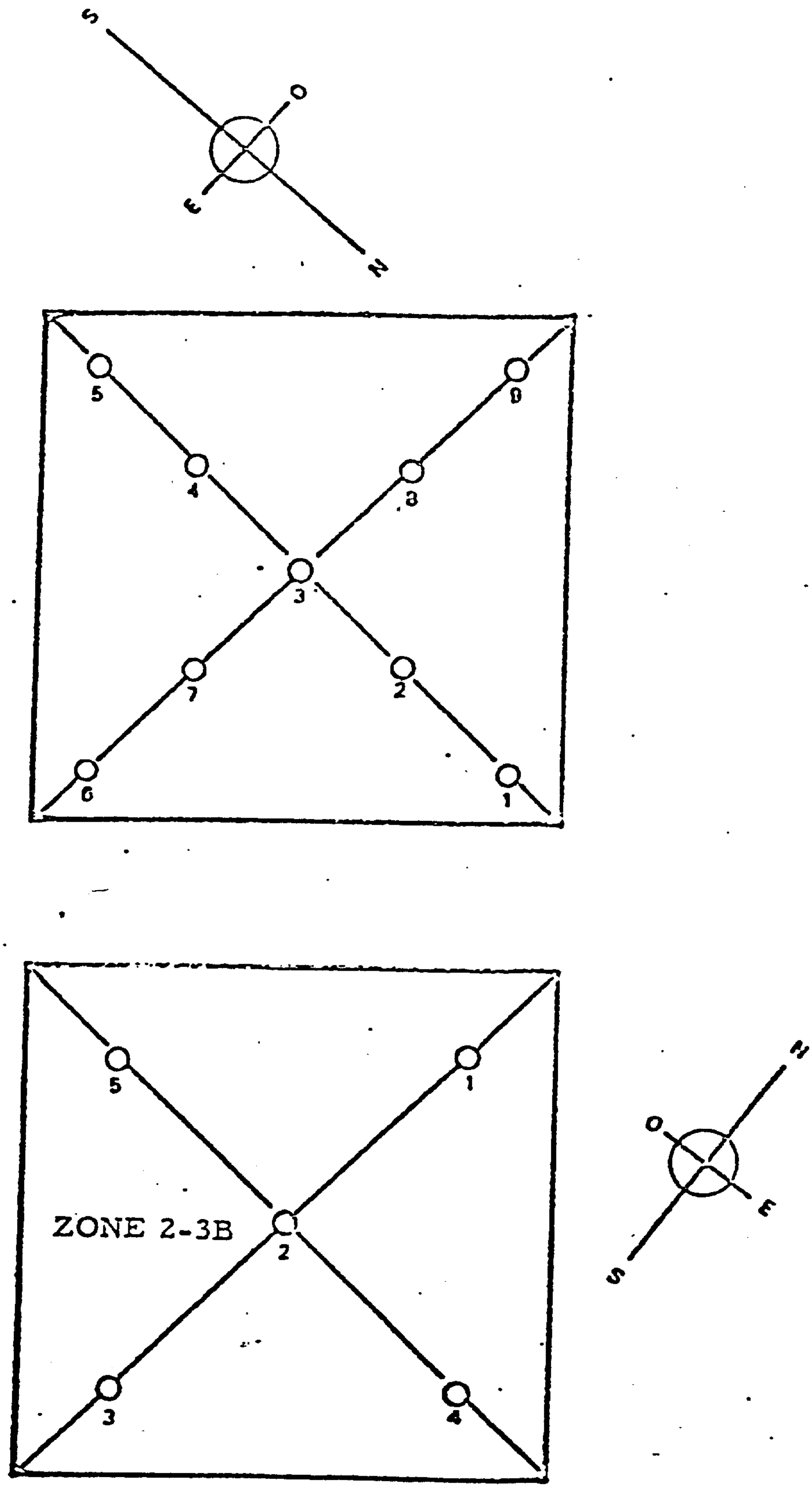

Figure 3. Location of sampling points.

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Discussion

Mr. C. Myttenaere:

Have soil-plant relationships been established for soil in place or for soil whose surface layer has been removed?

Mrs. C. Alvarez-Ramis:

For the layer (5 cm deep) which is in place.