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Firmground ichnofacies recording high-frequency marine flooding events (Langhian transgression, Vallès-Penedès Basin, Spain)

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⊣ **A B S T R A C T** ⊢

The decapod burrow *Spongeliomorpha sudolica* occurs associated with transgressive firmgrounds in the transition between Aragonian continental red beds and Langhian marine units in some of the inner sectors of the Vallès-Penedès Basin. This ichnospecies designates branching burrow systems with scratch marks in the walls produced by marine crustacean decapods. The occurrence of *Spongeliomorpha* represents an example of the *Glossifungites* ichnofacies. The several horizons where the traces are found are intercalated with continental red beds a few meters below the main transgressive surface, which is overlain by fossiliferous marine sandstones. The *Spongeliomorpha*-bioturbated layers record short, high frequency marine flooding surfaces that may be related either to actual sea-level changes or to variations in tectonic subsidence or sediment input. In any case, these flooding events punctuated the early phases of the Langhian transgression in the basin.

KEYWORDS | Ichnology. *Spongeliomorpha*. Miocene. Sequence stratigraphy.

INTRODUCTION

The Vallès-Penedès Basin is a Miocene extensional basin developed in the north-eastern part of the Iberian Peninsula. It is well known from a stratigraphic, tectonic, paleontologic and paleogeographic point of view. However, ichnological studies are limited to bioerosion structures on marine shells (Batllori and Martinell, 1992) and bioturbation traces of irregular echinoids (Gibert and Martinell, 1994).

This study concerns the stratigraphy, paleontology and ichnology of two previously undescribed outcrops situated in the internal part of the basin. The research focuses par-

ticularly on the occurrence of crustacean burrow systems with scratched walls, *Spongeliomorpha sudolica*, which occur associated with firmgrounds in the transition from continental to marine units. The paleobiology of the ichnotaxon and the sequence stratigraphic significance of its occurrence are discussed.

GEOLOGICAL AND STRATIGRAPHICAL SETTING

The sections studied herein are located west of the city of Sant Cugat del Vallès, about 15 km north of the city of Barcelona in NE Spain (Figs. 1 and 2). The area is part of the Vallès-Penedès Basin, a half-graben situated

within the Catalan Coastal Range. This basin is related to an extensive system of grabens and horsts that make up the northwestern margin of as the Valencia Trough, developed during the Neogene between the eastern margin of the Iberian Peninsula and the Balearic Islands (Fontboté et al., 1990; Roca et al., 1999). The Vallès-Penedès Basin is narrow (12-14 km) and extends for more than a 100 km in a southwest-northeast direction parallel to the present shoreline (Fig. 1A). The northwestern boundary corresponds to the Vallès-Penedès Fault, which was active between the latest Oligocene?-Early Miocene and the Late Miocene and separates the basin from the highs of the Prelittoral Range. The southeastern boundary possesses only minor faults and it is constituted by the Garraf-Montnegre Horst (Cabrera et al., 1991; Cabrera and Calvet, 1996).

The sedimentary filling of the Vallès-Penedès Basin is composed of up to 3000 m (near the northwestern fault) of mostly non-marine alluvial sequences punctuated by marine wedges. At least three episodes of marine transgression in the Late Burdigalian, the Langhian and the Serravalian have been recognized (Cabrera et al., 1991, 2004; Cabrera and Calvet, 1996). The Langhian (Middle Miocene) transgression was the most extensive, penetrating into the inner sector of the basin (Fig. 1B). During this interval most of the basin was characterized by siliciclastic deposition fed by coastal fans associated with the northwestern topographic highs. Concurrently, small carbonate platforms developed upon the Garraf-Montnegre Horst, protected from terrigenous input.

The marine units that crop out near Sant Cugat represent the most internal marine facies within the basin. They have been known for a long time (Almera, 1898). Rosell et al. (1973) and, more recently, Cabrera et al. (1991) and Agustí et al. (1997) have provided detailed stratigraphic accounts. In the Western Vallès, the Langhian marine units overlay the Aragonian Lower Continental Units and are covered by the Aragonian to Turolian Upper Continental Units, both consisting mainly of alluvial fan red bed deposits. The paleontology of the marine units has been subject of several publications (Villalta and Rosell, 1966; Calzada et al., 1978; Batllori and Martinell, 1993; Batllori and García, 1997). Much of the previous research focused on sections that have subsequently been buried or destroyed. The outcrops that remain are small and rather isolated. The two localities that are studied herein, previously undescribed, are both in the surroundings of Sant Cugat and about 5 km distant from each other (Fig. 2).

OUTCROP DESCRIPTION

Can Cabanes

This outcrop is an artificial exposure located at the railway station of Sant Cugat immediately south of Can Cabanes (Figs. 2 and 3). Here, strata dip gently (13°) to the southwest. Two sections have been measured. The eastern section is the most complete, while the western
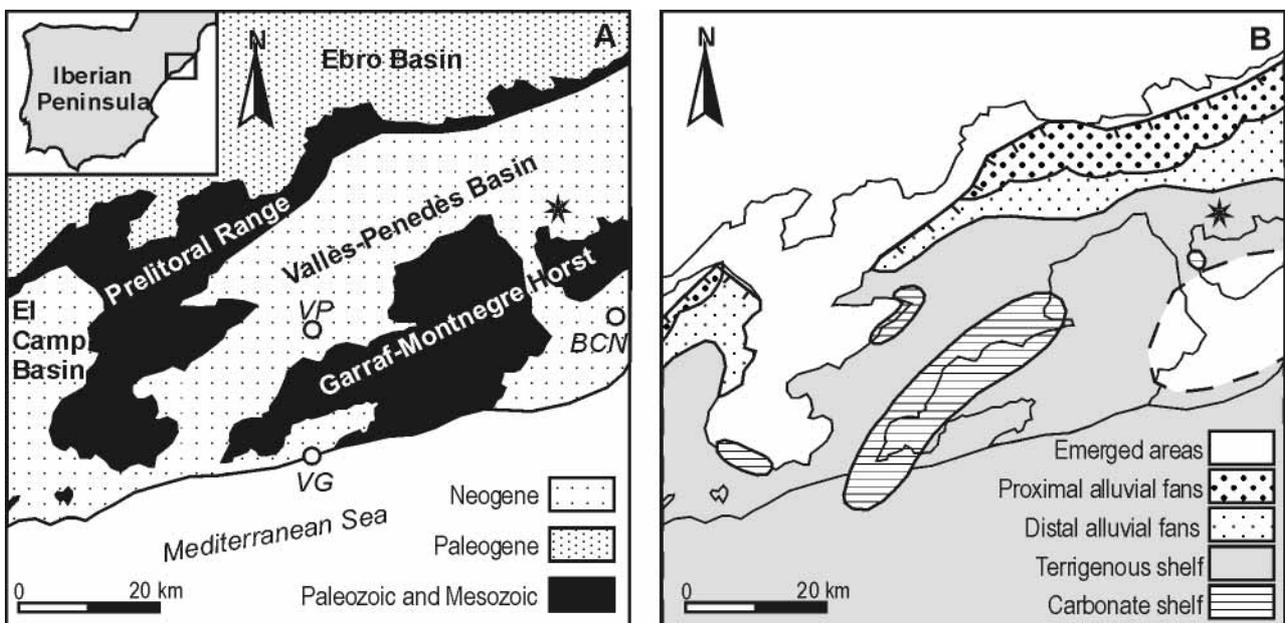

FIGURE 1 | **A) Synthetic geological map of the Vallès-Penedès Basin. BCN: Barcelona; VP: Vilafranca del Penedès; VG: Vilanova i la Geltrú. Upper left insert indicates position of the area within the Iberian Peninsula. B) Paleogeographic map of the Vallès-Penedès Basin during the Langhian. Stars indicate the position of the studied sector. Both maps modified from Cabrera et al. (1991).**
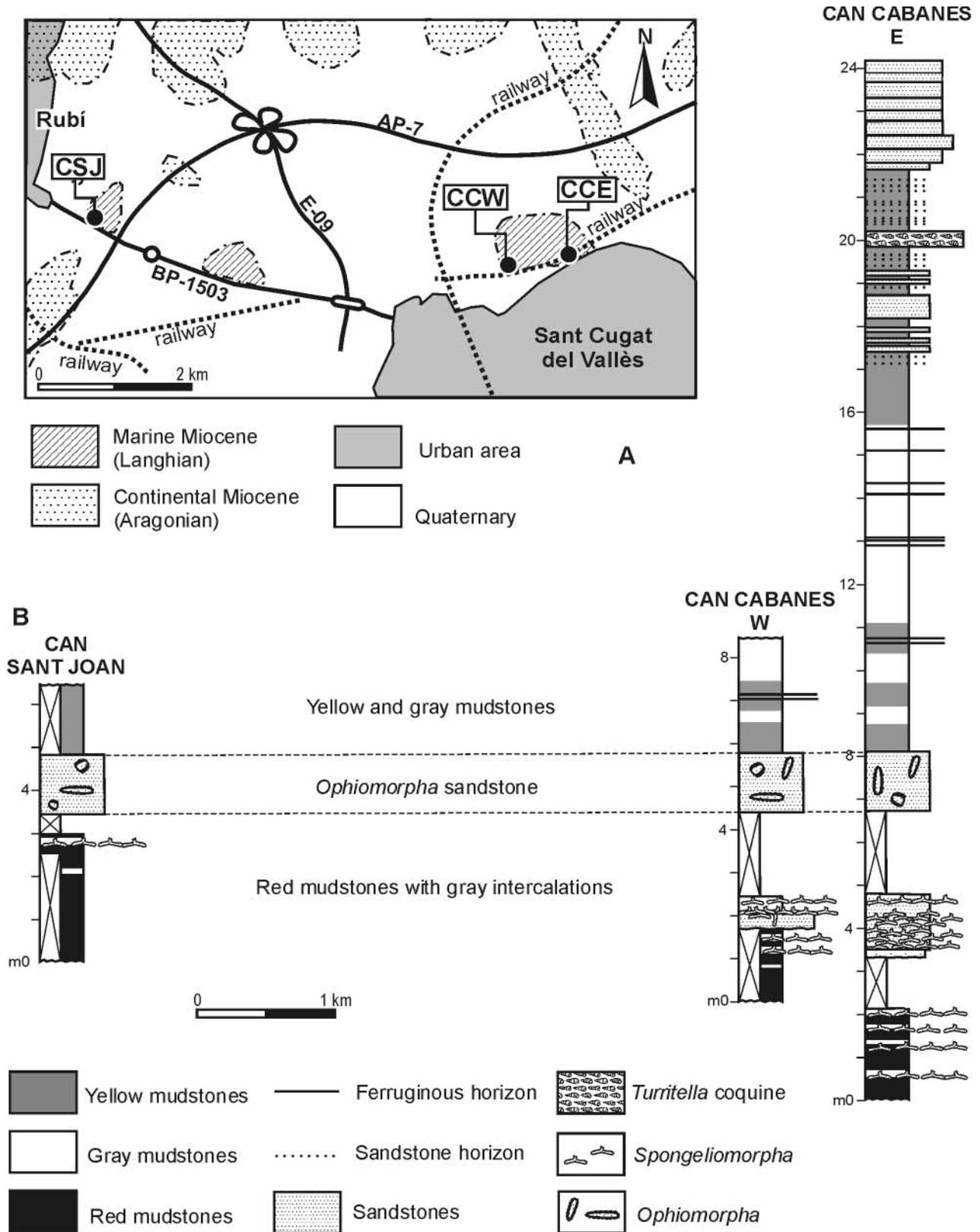
FIGURE 2 | **A) Geological map of the area between Rubí and Sant Cugat with location of the three measured sections: CSJ: Can Sant Joan; CCW: Can Cabanes West; and CCE: Can Cabanes East. B) Lithostratigraphic correlation of the three sections.**

section displays a repetition by faulting of the lower part of the first one.

Eastern section

This section is about 24 m thick (Figs. 2B and 3). The lowermost part consists of red mudstones with thin (10-20 cm thick) intercalations of gray mudstones, which contain *Spongeliomorpha sudolica*. The filling of the burrows is composed of fine-grained sandstone with bioclasts, mostly oyster fragments and more rarely pectinids. Above one meter without exposure is a bed of fine-grained sandstone with intense bioturbation (ichnofabric index, i.i., 4-5, following Droser and Bottjer, 1986), consisting of *S. sudolica* and *Thalassinoides suevicus*. Following an additional 2 m covered section, another fine-grained sandstone is exposed. This is completely bioturbated (i.i. 5-6), with *Ophiomorpha nodosa* being the only recognizable ichnotaxon (Fig. 4B). These sandstone contains abundant fossils, including shells of oysters, anomiids, and pectinids (*Chlamys multistriata* and others); moulds of other bivalves (*Pteria* sp., *Glycymeris* sp., *Megaxinus bellardianus*) and gastropods (*Turritella turris*, *Conus mercati* and indeterminate naticids); and very rare echinoids (*Clypeaster* sp.). This bed is overlain by 9 m of discontinuously exposed mudstones that are yellowish-brownish in the lower and upper part, and bluish-grayish in the middle interval. Thin (millimetric) iron-oxide stained horizons are present. The mudstones contain abundant fauna consisting of bivalves (oysters, mytilids, nuculids, *Anadara diluvii*, *Cardium hians*), gastropods (*Athleta ficulina* and others), irregular echinoids (*Brissopsis* sp.) and rare decapods (*Pinnixa mytilicola*), together with carbonized plant remains. Trace fossils are scarce and are represented by some limonitized or sandstone-filled sinuous burrows similar to *Sinusichnus sinuosus*. The mudstones are overlain by an interval of very-fine- to fine-grained micaceous sandstone beds with

thickness between 10 and 20 cm (only one bed reaches 40 cm) intercalated with sandy yellowish mudstones. Reworked sandstone slabs, probably coming from this interval, exhibit echinoid resting traces (*Cardioichnus* isp., Fig. 4C), crustacean and annelid burrows (*Ophiomorpha nodosa* and *Palaeophycus* isp.), and possible bivalve trails (?*Protovirgularia* isp.). This unit is topped by a 40 cm-thick, almost monospecific coquina constituted by shells of *Turritella terebralis*, and more rarely *Anadara diluvii*. The section continues with almost 2 m of sandy, yellowish mudstones with a similar fossil assemblage to the one described above, culminating in a 2.5 m interval of medium- and locally coarse-grained sands in tabular beds of 10-20 cm.

Western section

This section is located 60 m to the west from the above outcrop and it is equivalent to the lower 11 m of the most complete section (Fig. 2). It is essentially identical but the main *Spongeliomorpha*-rich bed is thinner and is developed in finer grained sediment. Samples for a micropaleontologic study were taken in three different horizons of this section. Two came from the lower unit of interbedded red and gray mudstones (one from a red horizon and another one from the gray). The first yielded only some micromammal remains, mostly teeth. Three genera were identified, *Democricetodon*, *Spermophilinus* and *Glirudinus*, allowing to assign these deposits to MN 4 zone corresponding to the Lower Aragonian (personal communication, Isaac Casanovas, 2004). The gray horizon did not contain any fossils. The absence of any marine fossils suggests that this unit was deposited in a continental setting. The third sample, derived from the mudstones overlying the *Ophiomorpha*-dominated sandstone, contained abundant marine microfossils including echinoid spines, foraminifera (globigerinids, *Nonion* sp. and *Rotalia* sp.) and ostracodes.

FIGURE 3 | **Photograph of the outcrop at Can Cabanes (eastern section) showing the position of the lithostratigraphic units.**

Can Sant Joan

The Can Sant Joan stratigraphic section (Fig. 2) is located immediately northwest of the intersection of highway AP-7 and the road between Rubí and Sant Cugat (BP-1503). It is interpreted to be equivalent to the interval measured in the western section of Can Cabanes. Here, the fine-grained sandstone bed with *Ophiomorpha nodosa* (Fig. 5A) is well-exposed having a lateral continuity of several hundred meters. Abundant fossils have been recognized including bivalves (anomiids, oysters, pectinids, *Corbula gibba*, *Thracia dollfusi* and *Megaxinus bellardianus*), gastropods (naticids, *Pereiraea gervaisi* and others), and barnacles (*Balanus* sp.). Below that bed, a single *Spongeliomorpha sudolica* horizon has been identified in poorly outcropping gray mudstones interbedded with red mudstones. The smaller number of *Spongeliomorpha* horizons in this section compared to the eastern localities is considered to possibly be an artifact due to deficient exposure.

DESCRIPTION AND ICHNOTAXONOMY OF *Spongeliomorpha sudolica*

Descriptive ichnology

Spongeliomorpha sudolica is used here to designate branched burrow systems with scratched walls (Fig. 5). Their three-dimensional configuration corresponds to horizontally developed mazes with rare vertical shafts. The branching points are typically Y-shaped with three converging galleries forming angles of about 120° (Figs. 5A and 5B). These elements are horizontal to subhorizontal (rarely more inclined than 20°). The shafts originate at the center of some branching points and only very short por-

tions of them have been observed (Figs. 5A and 5B). The transverse cross-section of the horizontal elements is circular to gently elliptical. Diameter (or width in elliptical sections) ranges from 1.5 to 4.5 cm. It is constant in each burrow system although enlargements are associated with the branching nodes (Fig. 5B). Terminations, where observed, are acuminate (Figs. 5F and 5G). Some specimens display vertical retrusive spreiten (Fig. 5E). The burrow fill consists of fine-grained bioclastic sandstone, with the bioclasts mainly representing oyster and pectinid fragments. In some cases, the shell fragments are more abundant in the basal part of the burrow. The most striking feature of *S. sudolica* is the external bioglyph displayed in the walls (Figs. 5C and 5D). This bioglyph is constituted by short (about 1 cm), narrow (less than 1 mm), rectilinear ridges. The ridges exhibit two main symmetrical orientations at about 30° of the axis of the burrow forming a reticulate pattern. The bioglyph is equally present in all the walls of the burrow.

Burrows from both outcrops share the above features. Additional specimens from a third outcrop, Sant Marçal, have been studied upon material hosted in the Museu Geològic del Seminari Conciliar de Barcelona (Fig. 5G). Sant Marçal is located near the city of Cerdanyola, about 5 km to the northeast of Can Cabanes. Unfortunately, the section that yielded these specimens is not longer exposed and there is no record of their exact stratigraphic position.

Ichnotaxonomic discussion

The ichnogenus *Spongeliomorpha* was erected by Saporta (1887) from the Miocene of southern Spain. The absence of type material and the poor original description led to Bromley and Frey (1974) to consider *Spongeliomorpha* as a *nomen dubium* that had to be abandoned.
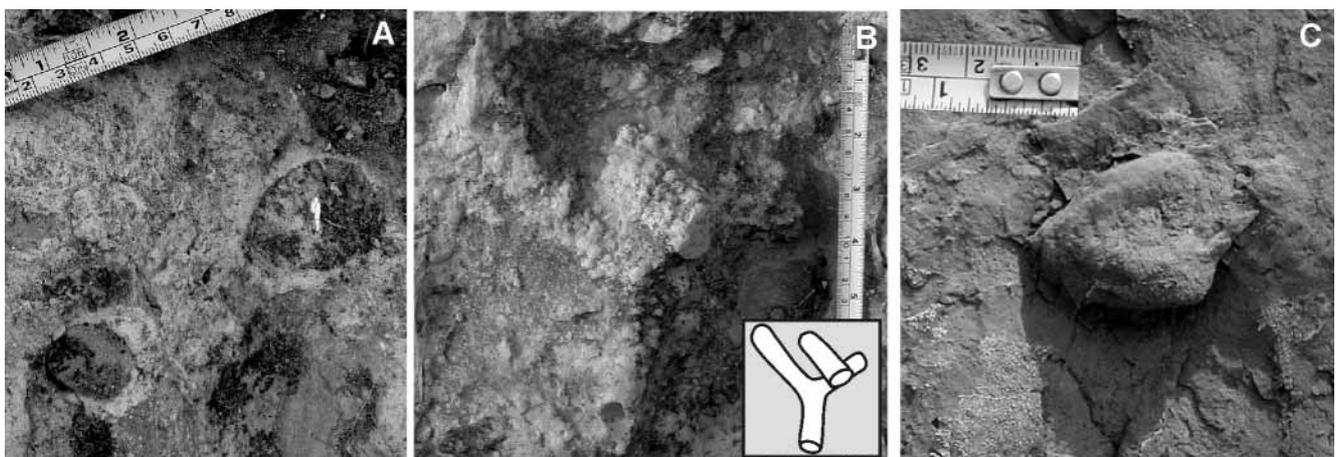

FIGURE 4 | **Trace fossils from the marine units. A)** *Ophiomorpha nodosa*, **two transverse cross sections in sandstones at Can Sant Joan. B)** *Ophiomorpha nodosa*, **burrows in three dimensions in a sandstone bed at Can Cabanes. Sketch in the insert at the lower right corner. C)** *Cardioichnus* **isp., hyporelief in a sandstone bed at Can Cabanes. Scale in centimeters and inches.**
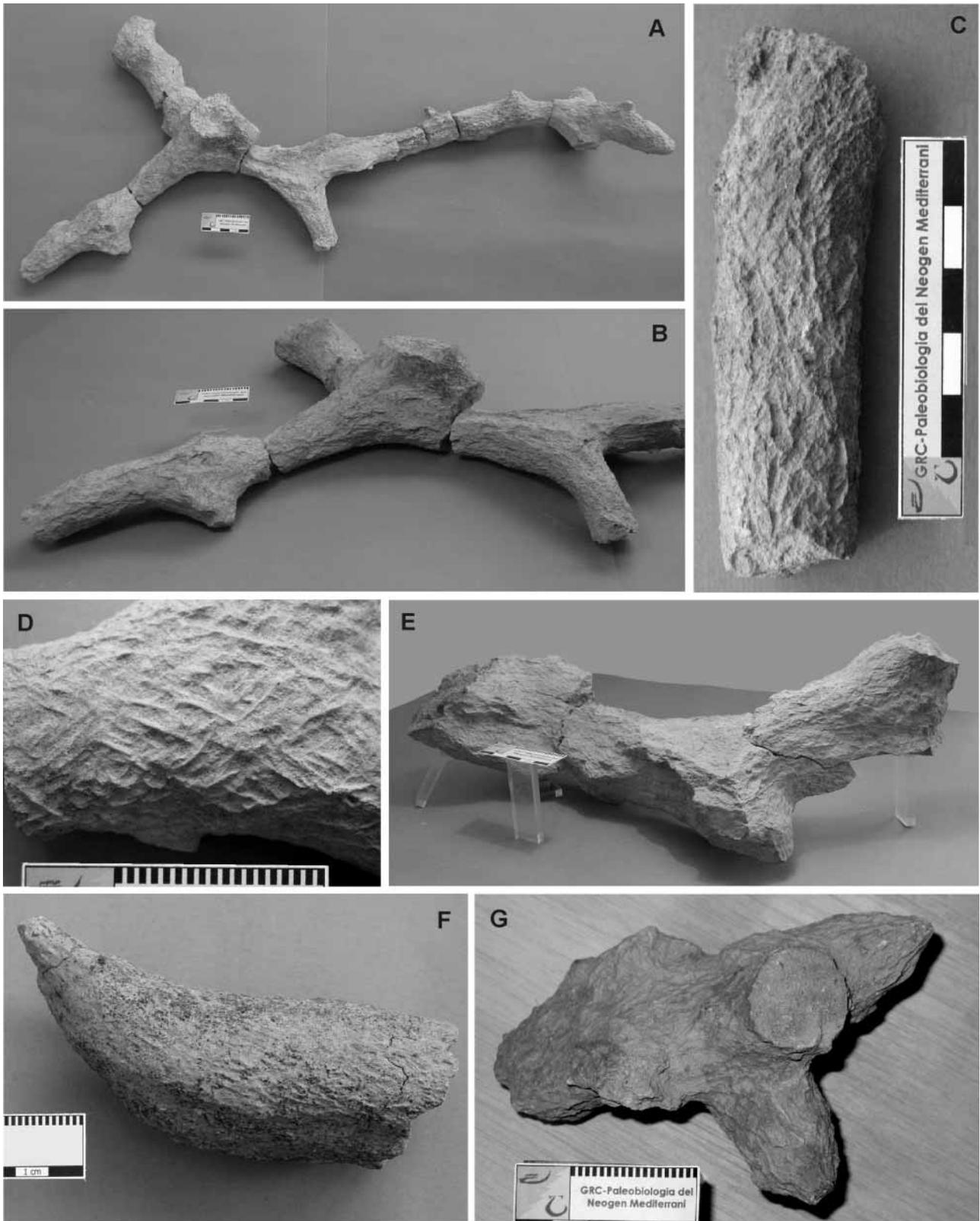
FIGURE 5 | *Spongeliomorpha sudolica.* A) Specimen displaying the typical branching configuration, Can Sant Joan. B) Detail of the same specimen showing the beginning of a shaft from the branching node. C) Fragment of a burrow showing the reticulate bioglyph, Can Cabanes. D) Detail of the scratched pattern of the walls, Can Sant Joan. E) Part of a burrow system with vertical shifting of the tunnels, Can Sant Joan. F) Acuminate cul-de-sac termination, Can Cabanes. G) Specimen displaying two acuminate terminations (top view), Sant Marçal (specimen 31836 of the collection of the Museu Geològic del Seminari Conciliar de Barcelona). Large rectangles in scale bars are centimeters, the smaller ones are milimeters.

Later, Calzada (1981) revisited the type locality and revalidated the ichnotaxon based on description of topotypic material.

Spongeliomorpha shares a similar configuration with the ichnogenera *Thalassinoides* and *Ophiomorpha*. The three are distinguished by the nature of the burrow walls, with bioglyphs in *Spongeliomorpha*, smooth in *Thalassinoides* and mammalated in *Ophiomorpha*. Fürsich (1973) and, more recently, Schlirf (2000) considered that the differences between those three ichnotaxa should not rank at ichnogeneric level and proposed *Ophiomorpha* and *Thalassinoides* to be junior synonyms of *Spongeliomorpha*. This discussion is beyond the scope of this paper.

Muñiz and Mayoral (2001) reviewed the known ichnospecies of *Spongeliomorpha*. They are defined mostly based on the features of the wall bioglyph. The material from Sant Cugat displays the diagnostic features of *Spongeliomorpha iberica* Saporta, 1887, because of the reticulate bioglyph resulting from the intersection of two main sets of rectilinear ridges oblique in relation with the axis of the burrow. Recently, Schlirf (2000) pointed out that *S. iberica* is synonymous with *Spongeliomorpha sudolica* (Zaręczny, 1878). The latter was erected from the Cretaceous of Poland as a sponge, *Spongia sudolica*, but Marcinewski and Wierzbowski (1975) demonstrated that it was a crustacean burrow. Bioglyph features of the ichnospecies *sudolica* are identical to those of *iberica* and so, the first remains valid because of the laws of priority.

PALEOBIOLOGICAL AND PALEOENVIRONMENTAL SIGNIFICANCE

Paleobiology

The bioglyph present in the walls of *Spongeliomorpha* records the digging activity of a multi-legged animal, such as an arthropod. Crustaceans have been proposed as the most feasible tracemakers for the marine representatives of the ichnogenus (D'Alessandro and Bromley, 1995; Muñiz and Mayoral, 2001). Several groups of modern decapods are known to construct branched burrow systems with configurations comparable to those exhibited by *Spongeliomorpha sudolica*, including thalassinidean shrimps (e.g. Nash et al., 1984; Bishop and Bishop, 1992), brachyuran crabs (e.g. Atkinson, 1974), and astacid lobsters (Rice and Chapman, 1971). Descriptions of modern burrows with scratched walls are scarce. Asgaard et al. (1997) described this feature in the U to Y shaped burrows of the thalassinidean *Upogebia mediterranea*.

Two ichnospecies of *Spongeliomorpha*, *S. carlsbergi* and *S. mildfordensis*, have been described from non-marine lacustrine settings (Bromley and Asgaard, 1979; Metz, 1993). Their configuration is different than that of *S. sudolica* in having T-shaped or irregular branching, respectively. Based on their different configuration and paleoenvironmental setting, they have been attributed to the activity of insects or insect larvae.

The functionality of decapod burrow systems is diverse and often complex (see Griffis and Suchanek, 1991; Bromley, 1996). In the case of *Spongeliomorpha*, D'Alessandro and Bromley (1995) proposed that the chambers that characterize *S. sicula* were constructed with the purpose of gardening (maturation chambers of organic material) or breeding. Those chambers are not present in *S. sudolica*. Muñiz and Mayoral (2001) described *Spongeliomorpha* intergrading to structures such as *Teichichnus* and *Phycodes* interpreted to be the work of a deposit-feeder. Deposit feeding does not appear to be a likely alternative for the *Spongeliomorpha* from Sant Cugat. They lack any structure suggestive of systematic exploitation of the substrate. We interpret them as dwelling burrows (domichnia) of suspension feeders or surface detritus-feeders.

Paleoenvironment

Spongeliomorpha is known from continental, shallow marine and deep marine settings. Continental examples are only known from the Triassic and they correspond to the ichnospecies *S. carlsbergi* and *S. mildfordensis* (Bromley and Asgaard, 1979; Metz, 1993). In the marine realm, *Spongeliomorpha* is most common in shallow and marginal marine settings (e.g. Calzada, 1981; D'Alessandro and Bromley, 1995; Muñiz and Mayoral, 2001) but is also present in bathyal carbonates (Bromley and Allouc, 1992) and deep-sea fans (Uchman, 1998).

The burrows from Sant Cugat are excavated in red non-marine mudstones, and filled by nearshore bioclastic sands. Thus, we interpret them as having been produced in a nearshore setting.

The preservation of the bioglyphs is indicative of the firm nature of the substrate. Firmgrounds may result from exhumation of muds dewatered by compaction and/or by subaereal exposure (Pemberton and Frey, 1985; Gingras et al., 2000). In carbonate sediments, they may be also induced by sediment starvation and early initial cementation (Bromley and Allouc, 1992).

THE *Spongeliomorpha* ASSEMBLAGE IN THE SEILACHERIAN ICHNOFACIES MODEL

The Ichnofacies model proposed by Seilacher (1964, 1967) has been completed over the years to constitute a

useful paradigm for the study of marine and continental ichnology (see Gibert and Martinell, 1998 and Pemberton et al., 2001 for a review). The *Spongeliomorpha* assemblage described herein fits within the *Glossifungites* ichnofacies. This ichnofacies was proposed by Seilacher (1967) and its definition was later refined by Frey and Seilacher (1980). It is characterized by uncompacted, sharp-walled (often with bioglyphs), unlined, passively infilled dwelling burrows constituting low-diversity but commonly high-abundance ichnofaunas developed upon firmgrounds. The *Glossifungites* ichnofacies is most common in shallow marine settings but also known from deep marine strata (Hayward, 1976; Bromley and Allouc, 1992). Common constituents of this ichnofacies are *Thalassinoides*, *Spongeliomorpha*, *Rhizocorallium* and *Diplocraterion*.

IMPLICATIONS FOR SEQUENCE STRATIGRAPHY

The *Glossifungites* ichnofacies is a substrate-controlled ichnofacies recording activity of marine organisms in firmgrounds. Those firmgrounds are related to omission surfaces linked to pauses in sedimentation generally accompanied by erosion. MacEachern et al. (1992) highlighted the fact that many of these discontinuities were boundaries of stratigraphic significance and referred to them as *Glossifungites*-demarcated discontinuities. Following those authors, the *Glossifungites* ichnofacies is found in relation with three types of stratigraphic surfaces: 1) lowstand erosive surfaces, when these are produced in marine or marginal-marine settings (e.g., submarine canyons, Hayward, 1976); 2) marine flooding surfaces, constituting parasequence boundaries, associated to transgressive erosion (e.g., Gingras et al., 2002); and 3) amalgamated (coplanar) lowstand and transgressive erosion surfaces (e.g. Abbot and Carter, 1994; MacEachern et al., 1999; Savrda et al., 2001). Savrda (1995) agreed with those three scenarios and considered that firmground ichnofacies were most ubiquitously linked to coplanar surfaces. Firmgrounds are mostly developed in fine-grained sediments and so, the same stratigraphic surfaces will have a different ichnofacies expression in coarser-grained or hardground substrates.

Gingras et al. (2000) cautioned that *Glossifungites* surfaces may also be related to autocyclic erosional processes (e.g. channel avulsion). Stratigraphically significant *Glossifungites* ichnofacies have to be laterally extensive and commonly the underlying and overlying deposits represent different environments.

In the case studied herein, the *Glossifungites* ichnofacies represented by each *Spongeliomorpha* horizon appears to record repeated marine incursions upon alluvial red beds. The sequence of events between episodes of marine flooding would have been as follows (Fig. 6):

1. Marine flooding of the alluvial coastal plain (or distal parts of alluvial fans), probably associated with erosion. Chemical processes associated with submersion of the muds may have caused their reduction and their change of color from red to gray. Nevertheless, the mudstones were most likely deposited in a continental setting as pointed out by the complete absence of marine fossils and the presence of micromammal remains.

2. Colonization of the submerged firmground by marine decapods producing *Spongeliomorpha*. Bioglyphs on the burrow walls evince the firm character of the substrate, which was the result of previous subaereal exposure and/or exhumation by ravinement. This colonization implies a certain period during which neither important erosion nor major deposition took place. Hence, *Spongeliomorpha* records the approximate timing of the flooding event.

3. Sedimentation of littoral sands. Sand deposition had to be in part contemporaneous with the activity of the burrowers. This is demonstrated by the existence of vertical spreiten constituted by bioclastic sands in some of the burrows (fig. 5e). These spreiten are interpreted as sandy laminae deposited in the base of the tunnels that forced the animal to shift its burrow upward. Nevertheless, at a
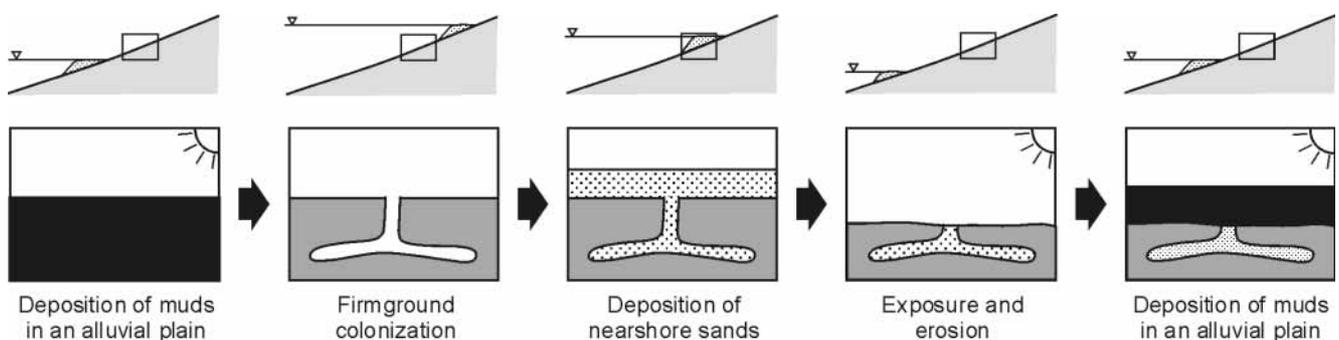

FIGURE 6 | **Diagram showing the sequence of events leading to the formation of a *Spongeliomorpha* horizon. See further explanation in the text.**

| Deposition of muds in an alluvial plain | Firmground colonization | Deposition of nearshore sands | Exposure and erosion | Deposition of muds in an alluvial plain |

later stage the sand filled the decapod burrows and probably inhibited the production of new dwellings. The nearshore nature of the sandstone is evidenced by the presence of oyster and pectinid fragments. These sands were probably deposited during the initial stages of regression.

4. Subaerial exposure and erosion. As shoreline prograded, the previous deposits were subaerially exposed, leading to the erosion of the sands and the truncation of the upper parts of the burrows. It is not possible to estimate the amount of erosion that took place.

5. Deposition of alluvial muds resumed probably when base level rose again or due to an increase in sediment input.

Glossifungites ichnofacies developed on non-marine mudstones representing marine flooding surfaces have been described by Dam (1990) and Bhattacharya and Walker (1991; see MacEachern et al., 1992 for discussion). However, in both cases the firmground trace-fossil assemblage is restricted to one single surface overlain by marine deposits that can be interpreted as a coplanar surface. In Sant Cugat, the horizons with *Spongeliomorpha* record high-frequency transgressive pulses before the installation of a more permanent body of water in the area. Each couplet constituted by the sand-infilled *Spon-*

FIGURE 7 | **A) Idealized sketch showing the position of the studied sections in a simplified stratigraphic chart. The uppermost erosive surface would correspond to a transgressive ravinement surface. B) Simplified sketch showing the sequence stratigraphic significance of different surfaces and deposits associated to the *Spongeliomorpha* horizons.**

geliomorpha and the underlying red mudstones (Figs. 6 and 7) records a transgressive-regressive cycle (a fundamental sequence in the sense of López-Blanco et al., 2000). The burrows and their fillings are the only marine record of each cycle, and thus are the only evidence of the marine flooding events within the continental section.

In the most complete section (Can Cabanes east), five transgressive surfaces are identified by the presence of *Spongeliomorpha*. The last is the most important as reflected by its greater thickness and burrow density. It is overlain by a bed of bioclastic sandstones with *Ophiomorpha* followed by sandy yellowish mudstones and then bluish mudstones. These deposits constitute the transgressive part of the marine unit. The upper part of the section with increasing sand content corresponds to the following regression. Thus, the overall section constitutes a lower order transgressive-regressive cycle.

The origin of *Spongeliomorpha*-recorded cycles remains unclear. They could correspond to actual high-frequency sea-level fluctuations or to relative variations due to changes in tectonic subsidence or sediment input. In any case, these events would have overprinted the transgressive tendency of the lower order transgressive-regressive cycle recorded by the overall section. Therefore, *Spongeliomorpha* herein enables recognition of high frequency transgressive-regressive cycles within a greater, lower order transgressive system tract (Fig. 7A). For each one of these cycles, the *Spongeliomorpha* walls can be assimilated to a flooding surface, while the erosive surface above the burrows would correspond to an erosional regressive surface (Fig. 7B). The continental red beds above and below the erosive surface may represent deposits related to relative sea-level rise, while the *Spongeliomorpha* marine infilling records sediments deposited during initial stages of the regression.
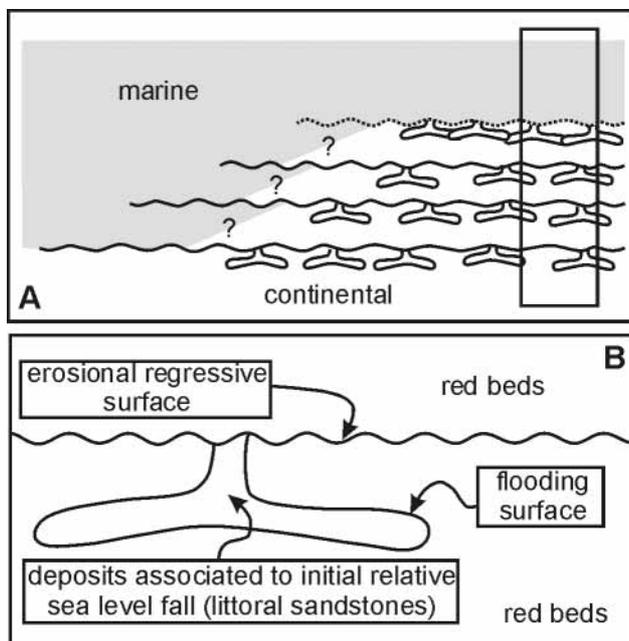
CONCLUSIONS

The presence of *Spongeliomorpha sudolica* at the base of the Langhian marine units in the Vallès-Penedès Basin records the activity of decapod crustaceans in submarine firmgrounds. The *Spongeliomorpha* horizons occur intercalated within continental red mudstones and they constitute the only evidence of the existence of high frequency marine flooding pulses punctuating the lower order Langhian transgression. These pulses could have been related with actual sea-level fluctuations or with relative changes derived from variations in tectonic subsidence or sediment input.

The *Spongeliomorpha* assemblage is a representative of the *Glossifungites* archetypal ichnofacies. This

ichnofacies is most commonly present associated to surfaces with stratigraphic significance. The example in the Vallès-Penedès Basin constitutes an additional case demostrating the value of *Glossifungites*-demarcated discontinuities to understand the evolution of sedimentary basins. Nevertheless, it differs from most other described occurrences in the fact that it records high order transgressive-regressive cycles.

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