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REPLY

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Reply to: Marques and Andrade (1993) [*Journal of Coastal Research*, 9(4), 1129–1135, Re: Discussion of Dias, J.M.A. and Neal, W.J., 1992. Sea Cliff Retreat in Southern Portugal: Profiles, Processes, and Problems. *Journal of Coastal Research*, 8(3), 641–654.

INTRODUCTION

We have read MARQUES and ANDRADE's (1993) lengthy discussion of DIAS and NEAL (1992) with interest, and some confusion as to their exact main points of contention; given that they seem to disagree with much of our presentation. DIAS and NEAL (1992) applied the cliff profile analysis method of EMERY and KUHN (1982) to a reach of cliffed coast between Olhos de Água and Quinta do Lago (Ancão); presented a general cliff retreat model based on field observations; and divided the study area into 3 zones based on cliff types, measured short-term cliff retreat, and human impact on the cliffs, including examples. The published paper was a summary of a presentation at a 1989 Portugal field symposium (PSUTY *et al.*, 1992). We stand by our presentation, the results, and general conclusions. We do apologize for the error introduced in the drafting of DIAS and NEAL (1992) Figure 9 in which the profile reference points should be in alignment in the columns and their heights should remain constant through time (MARQUES and ANDRADE, 1993, 1.d). Nevertheless, the figure conveys the nature of the cliff profiles and the rapidity of cliff retreat in Zone II.

MARQUES and ANDRADE (1993) often confuse generalization and detail, for example, their comments 1.a, 1.b, and 1.c. The generalizations of the DIAS and NEAL (1992) abstract reflect the details of the narrative, and speak to the general study area as well as defined zones. For example, when we refer to a 2 km reach around Vale de Lobo we are not restricting the discussion only to the cliff fronting the resort (DIAS and NEAL, 1992, Figure 3).

Here, we address the apparent main topics of the discussion (MARQUES and ANDRADE, 1993) which are their dissatisfaction with (1) the lack of an extensive literature review, (2) various aspects of the cliff profiles and associated descriptions, including the application of the EMERY and KUHN (1982) method, (3) the zonation of the study area, and (4) the incompatibility between erosion rates determined by our field measurements and the air photo studies of Marques and others (*e.g.*, MARQUES and ROMARIZ, 1991).

GRAY LITERATURE AND BURIED DATA BASES

Our objectives did not include providing an extensive literature review. We welcome such from MARQUES and ANDRADE (1993), however, their criticism seems to imply that DIAS and NEAL (1992) should have cited references from between 1990 and 1992 (*e.g.*, MARQUES and ROMARIZ, 1991; MARQUES, 1991), and that some critical data base was overlooked, which is not the case. If they had read the introduction by PSUTY *et al.* (1992), perhaps they would have surmised that the DIAS and NEAL (1992) paper was initially written in 1989, and a final revision in 1991. Therefore, we did not compare our results to theirs.

MARQUES and ANDRADE (1993) cite 16 references in their "Setting and Previous Work" section which, along with 2 additional references in later sections, pertain directly to the study area.

These include 3 theses, 3 unpublished reports, 4 abstracts, and 2 reports from congress and seminar proceedings that are far from mainstream literature.

A literature base in which over half of the references are unpublished or abstracts suggests two problems. First, their discussion rests on data that are difficult to obtain. Second, a considerable body of coastal research in Portugal is either not being published, or is buried in obscure publications with limited circulation. In addition, we note that MARQUES and ANDRADE (1993) are selective in what they report from some of their own work in support of their discussion, and do not point out the discrepancies between their results and those of other workers in the same area.

We believe the readers of this discussion-reply would find it difficult to obtain the data bases on which MARQUES and ANDRADE (1993) base much of their discussion. Planners and decision makers in Portugal would find it equally difficult. When the senior author requested two of the referenced D.G.P. (Port Authority) reports he was informed that the reports were not yet approved by the D.G.P. and were confidential. Even MARQUES and ANDRADE (1993, 1.e) infer an older data base by giving a second-hand reference (GRANJA, 1984). GRANJA (1984) and GRANJA *et al.* (1984), referring to a D.G.P. study, indicate the sea advanced around 120 m between 1918 and 1943, and 60 m between 1943 and 1962. No data base is reproduced, no method discussed, and no indication is given as to whether the retreat was cliff recession or beach migration (we suspect the information may have been for Quarteira beach). MARQUES and ANDRADE (1993, 1.e) do not point out that the resulting retreat rates are 6 to 10 times higher than the rates they defend from their studies, or that earlier in their discussion they discarded older cartographic studies (*e.g.,* 1918–1943)!

CLIFF ORIGINS, EVOLUTION, AND PROFILES

A major contention of MARQUES and ANDRADE (1993, 1.l) is that the use of the EMERY and KUHN (1982) method is unjustified, and call for an unspecified alternative. We take exception. The method is widely recognized and its straight-forward application in our study area demonstrated that marine erosion is dominant over subaerial erosion, and that near Quinta do Lago the cliffs have attained the "fossil" stage (Zone III). The method is ideal for a rapid understanding of the type of erosion on a cliffed coast. We also noted the exception within the study area where the sigmoidal profile is due dominantly to marine erosion rather than subaerial erosion (DIAS and NEAL, 1992, p. 643).

The MARQUES and ANDRADE (1993, 1.m) comment regarding DIAS and NEAL (1992) Figure 1 misses the point of the paper. The figure provides the general regional geologic and coastal geomorphic setting, and was not the objective of the paper. Likewise, we are surprised that MARQUES and ANDRADE (1993, 1.m and 1.o) report that overhanging sections do not exist. Such profiles do develop [phase E of DIAS and NEAL (1992) model], although ephemeral, resulting in slides or rock falls soon after attainment (the same is true for sea notches). The concavity of the profile is visible and measurable by hanging a plumb line over the cliff edge (not an optical illusion)! One of the reasons why the cliffs of the study area are of interest is that their evolution over a year or two may correspond to a sequence of events and profile attainment that takes centuries or more in resistant cliffs, such as those developed in the dense dolomitic limestones of Cape St. Vincent.

The sequence of events noted above was the basis for the DIAS and NEAL (1992, p. 643) idealized cliff retreat model for the study area, based on field observations, and we find no evidence provided by MARQUES and ANDRADE (1993, 1.n) to support abandoning that model. We made no implications that the model is applicable to the cliffs west of the study area.

Cliffs cut in Miocene formations do occur in the westernmost part of Praia da Falesia, specifically in the transition from Praia da Falesia to Praia dos Olhos de Água; a lithological contrast responsible for the difference in coastal orientation. The Miocene cliffed zone lies to the west of our study area. Although these formations are poorly consolidated, they are not cohesionless and are better consolidated than the formations of the study area's red cliffs.

MARQUES and ANDRADE (1993, 1.m) are incorrect in stating that profile OA1 is located within the Miocene cliffs. The profile is near the western end of the red cliffs and slopes of 35° to 40° do not exist there. DIAS and NEAL (1992) Figure 3 shows that the coast is approximately rectilinear to the westernmost end of the study area (to just west of profile OA1) where there is an inflection in the coast at the lithological change. The neighboring Miocene cliffs are retreating slower than the red cliffs, and the resulting protuberance may protect the western end of the red cliffs from more rapid erosion, hence the low cliff retreat at station OA1.

MARQUES and ANDRADE (1993) reinforce our comments on mass wasting in cliff evolution, however, they (1.o) report no joint control was found, although joints have been recognized by other workers. For instance, the CONSULMAR (1979) study of Vale do Lobo reports that several joints were visible, more frequent parallel to the coast, sometimes presenting great continuity. As the cliff evolves, pressure release probably does result in lateral cracking, but we suggest that it is along regular joint sets, and, in either case, the result is the same (DIAS and NEAL, 1992, Figure 4).

The clay-silt (mud) contents of the cliff's clastic rocks as cited by MARQUES and ANDRADE (1993, 1.p) support our statement in regard to the high mud content of the coarse lithologies. According to the classification of FOLK (1974) these are muddy sands, gravelly muddy sands, and muddy sandy gravels.

MARQUES and ANDRADE (1993, 1.f and 1.g) attempt to place DIAS and NEAL's (1992) Table 1 in contexts for which it wasn't intended. The table presents retreat rates, not profiles or cliff heights. Our statement that some cliffs were observed to maintain their profiles with slight modification for at least two years is based on field observations throughout the study area, although the measurements presented in Table 1 (DIAS and NEAL, 1992) do suggest times of minimal modification for stations OA1, F15, and VL3. The general relationship between retreat and cliff height, as discussed, was true for the 5-year study period.

As originally noted (DIAS and NEAL, 1992, p. 643; and Figures 5 and 8), the cliffed coast is not straight, an important characteristic that is easily overlooked when working at the scale of standard maps and air photos. Because of local variation in retreat rate, protuberances develop. In stating the exception to the cliff height/retreat rate generalization, we did not use the term "headland" *sensu stricto*, but to indicate such protuberances that erode rapidly; resulting in the trend toward linearity of the coast. Similarly, the land surface, into which the cliffs are cut, is not flat. As the cliff retreats, cliff height may increase or decrease in response to the upland topography, and erosional intersection with gullies [*i.e.*, retreat rates change as the cliff topography is modified, so "irregularization" of the coast is not expected as implied by MARQUES and ANDRADE (1993, 1.g)].

DIAS and NEAL (1992) did not intend to imply that velocity and duration are equivalent. Retreat is related to the stages of the outlined cycle and depends on the number of cycles occurring in any given time interval. The greatest retreat occurs during the transition from phase A to B; a transition that is often instantaneous. Similarly, significant retreat occurs locally when a beach-gulley divide is breached. MARQUES and ANDRADE's (1993, 1.h) comment regarding the small area of gullies is of little solace to those suffering land loss. Marques and Andrade should visit the developments east of Quarteira during a rain storm.

THE COASTAL ZONES

In their conclusion MARQUES and ANDRADE (1993) question the division of the study area into three zones, implying that the division was based solely on contrasting cliff retreat rates. DIAS and NEAL (1992, p. 645) indicate the zones are differentiated on the basis of cliff type (*e.g.*, height, frequency of valley mouths, active versus "fossil" or protected), land use (human impact), and the character of the adjacent beach as well as cliff retreat rates. The two active zones shown in DIAS and NEAL (1992) Figure 3 have boundaries defined by natural features (western contact with the Miocene, Quarteira beach, beginning of barrier islands), and are the same as zones defined by MARQUES (1991). Our Portuguese reviewers, who have worked in the Algarve, found no problem with the defined zones and understood the discussion.

MARQUES' (1991, Table 1, p. 104) summary of retreat rates for the Algarve's cliffed coasts divides the coast into sectors including Olhos de Água–Ribeira de Quarteira and Quarteira–Ancão, the same as our Zones I and II! The same reference gives the following retreat rates: Olhos de Água–Ribeira de Quarteira, 0.2–0.3 m/yr (1947–1991 period of record), and Quarteira–Ancão, 2.5–1.3 m/yr (1980–1991 period of record), the latter upper value in close agreement with our results. These averages suggest that in recent years the Zone II cliffs retreated at a rate 4 to 12 times greater than Zone I, however, the averages are not based on equal periods of record. Note, however, that MARQUES and ANDRADE (1993) state that the main erosional event at Forte Novo occurred between 1976 and 1980 involving a total retreat of

30 m. These results, together with the Vale do Lobo study (CONSULMAR, 1979), indicate more rapid cliff retreat in Zone II, during the 1964–1991 interval, than in contrast to Zone I.

THE LONG AND SHORT OF CLIFF RETREAT

The crux of the MARQUES and ANDRADE (1993) discussion is that they do not want to accept the DIAS and NEAL (1992) data set or the implications of these short-term erosion rates. They refer repeatedly to the work of MARQUES and ROMARIZ (1991) and MARQUES (1991) to defend erosion rates on the order of 0.5 m/yr as follows:

Falesia	1947–1983	0.25 m/yr	2.2a)
Forte Novo	1947–1976	0.5 m/yr	1.q)
Vale do Lobo	1947–1980	0.5 m/yr	1.q)
Vale do Lobo	1947–1983	0.5 m/yr	1.k)

Their reference to a regional "global" average of 0.25 m/yr is of little significance to the study area, and is an attempt to minimize their comparative retreat rate.

By dismissing studies involving cartographic comparisons MARQUES and ANDRADE (1993) avoid discussing results that do not agree with their 0.5 m/yr rate, including some of their previous work. For example, ANDRADE *et al.* (1989) gave a mean retreat rate of 1.3 m/yr, and a range of 2.1 to 0.8 m/yr, for the red cliffs zone between 1951/52 and 1976; a result intermediate between those of MARQUES and ANDRADE (1993) and DIAS and NEAL (1992). Similarly, MARQUES and ANDRADE (1993) do not agree with results presented by GUILLEMOT (1979), GRANJA (1984), BETTENCOURT (1985), and BETTENCOURT and BRAUD (1986). Finally, they fail to report specifically that MARQUES (1991) presented mean retreat rates for Zone II as high as 2.5 m/yr from 1980 to 1991.

Consider that MARQUES and ANDRADE (1993) defend a retreat rate at Vale do Lobo of 0.5 m/yr for the intervals 1947–1980 and 1947–1983 (*i.e.*, 16.5 to 17.5 m of total retreat). Yet precise cliff profiling at Vale do Lobo shows 6 to 12 m of retreat between 1964 and 1976, and retreat of the same magnitude through the late 1970's (CONSULMAR, 1979); a total retreat nearly equal to that of MARQUES and ANDRADE (1993) for the 1947–1980 interval. This comparison suggests that either MARQUES and ANDRADE's (1993) average range is underestimated, or cliff retreat accelerated in the later part of the interval.

They imply higher short-term rates, such as those reported by DIAS and NEAL (1992), are only part of the variable, discontinuous pattern of cliff recession in time and space. They appear unwilling to consider that changes in land use or regional processes (*e.g.*, effect of the possible sea level rise is lightly dismissed) may alter retreat rates. Yet MARQUES and ANDRADE (1993) show no past episodes of such high variability for Zones I and II, although they studied interval sets of air photos (*i.e.*, 1947, 1958, 1974, 1980, 1983). Only the short-term 30 m retreat between 1976 and 1980 at Forte Novo is mentioned, and their interval of retreat rate cited in 1.q conveniently omits this 4-year record!

MARQUES and ANDRADE (1993, 1.i, 2.b, 1.j, 1.k, 1.q) repeatedly attempt to minimize the possibility that retreat rates are accelerating in Zone II, and the significance of human impact on that zone. In regard to the down-drift effects of the Vilamoura jetties and Quarteira groin field they state that at Forte Novo "the retreat rates indicated by DIAS and NEAL (1992) are only about 50% more intense (2.9 m/year and 3.3 m/year) than figures indicated by these authors for Praia da Falesia (1.7 m/year to 2.0 m/year)." We believe an increase of 0.9 to 1.6 m/yr in retreat rate is significant!

MARQUES and ANDRADE (1993) agree that the Quarteira coastal defenses have impacted the coast, but later state that their figures suggest the retreat intensity has declined east of Quarteira since 1980. MARQUES (1991), however, reported retreat rates of 2.5 to 1.3 m/yr for the Quarteira–Ancão reach from 1980 to 1991! GUILLEMOT (1979) provides evidence that the zone's sand supply was decreasing from at least the 1950's, and through the later construction of the coastal defenses. Although it is debatable whether or not Forte Novo replaced an earlier fort, its position in the 1947 air photo and the 1951 Portuguese Army 1:25,000 map support our original statement that the fort was well back from the cliff edge. Our data, the Vale do Lobo profiles from 1964 and 1976 (CONSULMAR, 1979), MARQUES' (1991) results, and the observations of others (*e.g.*, GUILLEMOT, 1979; GRANJA, 1984; BETTENCOURT, 1985) support the conclusion that the coastal defenses at Quarteira are impacting the Zone II cliff/beach line. ANDRADE *et al.* (1989) reported beach retreat rates of 1.0 to 3.5 m/yr; on average, higher than cliff retreat rates, suggesting strong beach narrowing. As the beach narrows, cliff retreat should increase.

MARQUES and ANDRADE (1993) set up other straw men in an attempt to dismiss recent high erosion rates. For example, they imply that the amount of sand being released from cliff erosion should cause beach "fattening," especially near the Vilamoura western jetty. GUILLEMOT (1979) reported the latter, however, significant volumes of sand probably are lost offshore, and by MARQUES and ANDRADE's (1993) own account, oceanographic conditions are poorly documented so modeling is questionable. Likewise, their comment about DIAS and NEAL (1992) Figure 7 is superflous; the figure's legend describes what the figure shows, including comparative cliff lines in the vicinity of Forte Novo. Their emphasis that erosion rates at some sites in Zone I are similar to some sites in Zone II should not be unexpected and does not change the average regional patterns.

FIELD AND PHOTO

DIAS and NEAL (1992) present short-term retreat rates based on field profiling. We did not present a detailed comparison to intermediate-term studies based on air photos, or predict future retreat rates. MARQUES and ANDRADE (1993) seem to insist that the retreat rate of 0.5 m/yr, based on air photos for the 1947 to 1983 interval, is the only acceptable rate. Likewise, they appear to question the validity of profiling as an alternative to using historic air photos. DANFORTH and THIELER (1992), in developing perhaps the most accurate shoreline analysis system to date, provide a literature review of quantifying shoreline position over time. They note that the most common approach for determining historical shoreline position changes is by measuring along evenly spaced orthogonals, not unlike field transects in profiling. DOLAN *et al.* (1979), primarily in reference to beaches, indicated that high-resolution measurements of changes in shoreline position are best achieved through either large-scale vertical air photos or beach profiling. SMITH and ZARILLO (1990) compared calculations of long-term recession rates using air photos and beach profiling techniques. Because of short-term erosion/accretion events, beach variability makes long-term aerial photography the method of choice. Cliffs, however, do not recover like beaches, so cliff edge position will vary only because of the variability of the retreat process and cycle.

By necessity of time and distance requirements, cliff retreat studies generally rely on air photo analysis. Frequent field profiling, however, may provide a more complete picture of the processes and cycle of cliff retreat. In profiling, cliff edge position is more precise; the cliff profile is obtained which may show both ephemeral features and ground controls not seen in air photos; scaling problems in which minor coastal irregularities are overlooked are avoided; and the timing and spatial patterns of cliff retreat are captured.

CONCLUSIONS

DIAS and NEAL (1992) reported on a short-term field study applying cliff profiling, field documentation of retreat rates, and examining human impact on the system. MARQUES and ANDRADE (1993) use the paper as a basis to discuss selected portions of their previous works, and attempt to create some controversy not implicit in the DIAS and NEAL (1992) paper. They question the use of the EMERY and KUHN (1982) method, but neither clearly discredit the method nor provide an alternative. They question the DIAS and NEAL (1992) cycle of cliff retreat based on field observation, but provide no alternative model, and apparently have overlooked local controls on cliff retreat in their own field work. They question the zonation of the coast used by DIAS and NEAL (1992), but do not accurately point out the sum of the criteria used, or the fact that the zones defined are essentially identical to those arrived at by MARQUES (1991)! They insist that their determined intermediate cliff retreat rate of 0.5 m/yr for Zone II persists into the 1980's, and attempt to minimize human impact on cliff retreat, in spite of evidence to the contrary presented by several authors, including DIAS and NEAL (1992), and even in other papers by MARQUES (1991) and ANDRADE *et al.* (1989).

MARQUES and ANDRADE (1993) should not be surprised at the intensity of the retreat process implicit in DIAS and NEAL (1992). They based their interpretation on intermediate-term averages (29 to 36 year interval) derived from air photo studies which (1) are not likely to reflect recent human impact on cliff retreat, (2) are generally not as accurate as field measurements, and (3) tend to deemphasize local ground control of erosional events.

Field profiling over the short term may yield retreat rates reflecting the discontinuous pattern of cliff retreat, either in major land-loss events or quiescence. In the case of Zone II (DIAS and NEAL, 1992) the rate of cliff retreat has accelerated in recent decades at the same time coastal development and defenses have increased. Therefore, we have either, by chance, made observations precisely during a time when the Quarteira–Quinta do Lago Zone is undergoing a natural accelerated retreat, unlike any previously recorded, or retreat rate acceleration has occurred mainly due to human impact as we outlined. Our observations, as well as those of previous authors, support the latter. MARQUES' (1991) data support our conclusion.

LITERATURE CITED

ANDRADE, C.; VIEGAS, A.L.; TOMÉ, A.M.B., and ROMARIZ, C., 1989. Erosão do litoral Cenozóico do Algarve. *VI Simpósio de Geologia Aplicada e do Ambiente: "Ambientes Geológicos Litorais"* (Lisboa, 28 Mar.–4 Abr., 1989), *Geolis*, v. III, fasc. 1/2, pp. 261–270.

BETTENCOURT, P., 1985. Géomorphologie et processus d'évolution recente de la côte sotavento (Algarve, Sud Portugal). *Rapport D.E.A. Université de Bordeaux I*, Bordeaux, France, 92p.

BETTENCOURT, P. and BRAUD, F., 1986. Remobilização das areias e trânsito sedimentar costeiro na costa oriental do Algarve (Sotavento) (resumo). *II Congresso Nacional de Geologia* (Lisboa, 29 Set.–2 Out., 1986), *Maleo*, v. 2, n. 13, p. 12.

BETTENCOURT, P.; FROIDEFOND, J.-M., and PERA, M.T.R., 1986. Geomorfologia e evolução recente do cordão arenoso no sotavento algarvio (resumo). *II Congresso Nacional de Geologia* (Lisboa, 29 Set.–2 Out., 1986), *Maleo* v. 2, no. 13, p. 12.

CONSULMAR (Empresa Turistica de Vale do Lobo), 1979. *Vale do Lobo Protecção das escarpas*. Unpublished report, 13p.

DANFORTH, W.W. and THIELER, E.R., 1992. *Digital shoreline analysis system (DSAS) user's guide version 1.0.* U.S. Geological Survey, Open-File Report 92-355, 19p.

DIAS, J.M.A. and NEAL, W.J., 1992. Sea cliff retreat in southern Portugal: Profiles, processes, and problems. *Journal of Coastal Research,* 8, 641–654.

DOLAN, R.B.; HAYDEN, B.; REA, C., and HEYWOOD, J., 1979. Shoreline erosion rates along the middle Atlantic coast of the United States. *Geology,* 7, 602–606.

EMERY, K.O. and KUHN, G.G., 1982. Sea cliffs: Their processes, profiles, and classification. *Bulletin Geological Society of America,* 93, 644–654.

FOLK, R.L., 1974. *Petrology of Sedimentary Rocks.* Austin, Texas: Hemphill, 182p.

GRANJA,, H., 1984. Étude géomorphologique, sédimentologique et géochimique de la "Ria Formosa" (Algarve—Portugal). Thèse 3ème cycle, n. 1944, Université de Bordeaux I, Bordeaux, France, 254p.

GRANJA, H.; FROIDEFOND, J.-M., and PERA, T., 1984. Processus d'évolution morpho-sedimentaire de la Ria Formosa (Portugal). *Bulletin de Institut Géologique du Bassin d'Aquitaine,* Bordeaux, 36, p. 37–50.

GUILLEMOT, E., 1979. Le littoral de la Region de Faro (Portugal). Étude de morphologie littorale. Thèse D.E.A. Université de Paris, Paris, France, 131p.

MARQUES, F.M.S.F., 1991. Taxas de recuo das arribas do litoral sul do Algarve e sua importância na avaliação de riscos geológicos. *Comunicações do seminário EUROCOAST "A zona costeira e os problemas ambientais"* (Aveiro, 18–20 Set., 1991), pp. 100–108.

MARQUES, F.M.S.F. and ROMARIZ, C., 1991. Nota preliminar sobre a evolução de arribas litorais. *4º Congresso Nacional de Geotecnia* (2–4 Out. 1991). Lisboa, Portugal. V. 1, p. 57–66.

PSUTY, N.P.; MOREIRA, M.E.S.A., and RICKETTS, PETER, 1992. A collection of papers from the Portugal field symposium May, 1989. *Journal of Coastal Research,* 8, 630.

SMITH, G.L. and ZARILLO, G.A., 1990. Calculating long-term shoreline recession rates using aerial photographic and beach profiling techniques. *Journal of Coastal Research,* 6, 111–120.