PRETREATMENT INFECTION AND PREMATURE FAILURE OF PCP-TREATED SOUTHERN PINE POLES

by

P.I. Morris and B.J. McAfee
Research Scientist
Forintek Canada Corp.
Western Laboratory
Vancouver, B.C.

Research Scientist
Forintek Canada Corp.
Eastern Laboratory
Ottawa, Ontario

Summary

A total of about 850 PCP-treated southern pine poles from four supplier/year combinations were inspected by a contractor. Their core samples were cultured to isolate wood-rotting basidiomycetes and thin sections were examined under the microscope. The incidence of decay based on inspections and wood rotting basidiomycete isolates was 4% for supplier A-85s, 3% for supplier A-86s and less than 1% for supplier B-85s. Microscopic examination revealed comparatively little damage in the groundline region. This was consistent with the distribution of decay and extensive end-grain penetration of preservative found in the intensive examination of cross sections of selected poles. Conclusive evidence for pretreatment infection as the origin of the decay problem came from the pattern of decay found in the intensive examination. This origin would also explain the distribution of fungi in the poles in service and the failure of some poles, due to decay, within five years of installation. At least 3% of A-85s could continue rapidly to lose strength unless there is sufficient preservative retention and penetration to prevent this.

Introduction

A number of instances of premature failure of southern pine poles treated with pentachlorophenol in P9 oil (PCP), supplied by supplier A in 1985, prompted a series of investigations of the problem. The investigation reported here covered two years supply of poles: 1985 and 1986, and two suppliers A and B. Supplier B was included for comparison with a 'more typical' population of poles. Although there had been reports of 1985 poles failing within 5 years, at the start of this project it was still uncertain whether the majority of the instances of premature failure were due to decay.

Forintek was requested to determine:

1. What is the incidence of decay in the population of poles for each of four supplier/year combinations?

2. Did the decay originate before or after treatment?

3. Is the situation static or will it get worse?

The results of this work were then correlated with the results of preservative analysis conducted by the laboratories of the utility concerned.

The project was done in three phases: The first phase was an examination of a limited number of decayed poles to provide the information necessary to develop the inspection procedures to be used in the field survey. The second phase was the field survey of the selected pole populations and the third phase was an intensive examination of decayed poles to confirm the pattern of decay.

Materials and Methods

Inspection of Poles in Service

Pole inspections were carried out by Quaile Engineering Ltd (New Market, Ontario) following a protocol set by Forintek based on information developed in phase 1. Relevant information was recorded on a checklist form. Poles were sounded with a hammer around the complete circumference, 20cm below and 2m above ground, to detect internal decay. The surface of the pole was also examined by inserting a blade parallel to the grain levering outwards and examining for splintering, indicating sound wood or brash fracture, indicating decay. This is referred to as the pick test. Borings were collected from the following 5 locations:

1. 10 cm below groundline adjacent to the base of the largest check (if no large checks - at suspect location).

2. 10 cm below groundline at suspect location (if no suspect location or if sample #1 was at suspect location then at 180° to sample #1).

3. 10 cm below groundline between cores 1 and 2.

4. 1.2 m above ground adjacent to the major check (if no large checks then at suspect location).

5. 30 cm vertically below bolt hole for cable attachment.

A depth gauge was inserted into each bore hole to estimate the extent of decay before the hole was filled with a preservative treated dowel. The presence and extent of decay in each pole was noted along with location and depth of major checks, shelling, woodpecker holes and mechanical damage. Cores were collected using sterile technique and forwarded to the laboratory in clean end-stapled straws via courier. Borings not

shipped immediately were kept refrigerated.

Mycological Examination of Cores

One core from the three (Figure 1) taken below groundline (#1) and the core taken at 30 cm below the bolt hole attachment (#5) were plated on 1.5% malt agar (MA) solidified with 1.5% agar. Benomyl (50% active ingredient) (4 mg/L^{-1}) was added to the autoclaved medium to selectively isolate basidiomycetes and the antibiotics tetracycline hydrochloride 50 $\mu g\ ml^{-1}$ and streptomycin sulphate 100 $\mu g\ ml^{-1}$ were added aseptically to inhibit the growth of bacteria.

Each core was flamed to sterilize the surface and cut into 4 equal lengths (A,B,C and D) which were set gently into the agar surface,(2 lengths per Petri plate. Petri plate were incubated at 27°C and 75% RH in darkness. Observations were made after 3, 7, and 21 days for the regeneration of microorganisms. All plates were re-examined at the end of the experiment to check for any slow growing fungi. Hyphae that regenerated on the core or the adjacent agar surface were observed microscopically for the presence of clamp connections, lateral bulges at the hyphal septa that characterize a fungus as a basidiomycete. Attempts were made to isolate all basidiomycetes into pure culture. Pure cultures were grown for 1-2 weeks at 27°C on MA, depending on the growth rate, before observation of mycelial mat characteristics (colour, texture, growth rate, margin, height), hyphae, specialized structures and spores. Undetermined cultures were grown and compared with identified cultures from the Forintek Culture Collection of Wood-Inhabiting Fungi or with descriptions in Nobles (25), Stalpers (31) and Wang and Zabel (34).

Microscopic Examination of Cores

The below-ground core #3 was used for microscopic examinations. Cores were divided into three sections; outer, middle and inner portion and free-hand radial sections were cut from each section of the core for estimation of cell wall damage. Sections averaging 5mm x 5mm were mounted in glycerin, scanned at 300X and 750X using transmitted light microscopy. Phase contrast and polarized light microscopy were used when necessary to increase resolution. Evidence of biodeterioration was ranked from 0 to 4 according to the scheme presented in Table 1.

The type of microbiological activity seen was classified as either sapstain, white-rot, brown-rot, soft-rot, or bacterial.

Examination of Decay Patterns in a Sample of Retrieved Poles

A total of twenty-five poles were intensively examined. The supplier and date were recorded for each pole together with any distinctive characteristics such as colour or surface decay. Any unusual features of the poles, such as fungus fruit-bodies were photographed. Samples of all fungus fruit-bodies were collected

in labelled bags. Each pole was then marked at 1 m intervals from the groundline to the top and to 2 m below ground. A vertical line was drawn at each position in line with the brand to provide orientation of all the discs to be cut from the pole. Discs 100 mm thick were cut at each of the marked positions and numbered as to distance from groundline. The collected discs for each pole were laid out and photographed as a permanent record; then the extent of decay was recorded for each disc. The areas of intermediate and advanced decay were marked on prepared record sheets. Intermediate decay was characterised by light brown discolouration and a slightly rougher area on the cut surface. Advanced decay was characterised by a distinct softening or shrinkage of the wood commonly accompanied by a dark brown discolouration. In addition any other features of the distribution of decay, sapstain or preservative distribution were also noted. Additional photographs were taken of representative features of the surfaces of the discs.

Results

Inspection of Poles in Service

The hammering and boring process yielded the following incidence of internal decay: 4% for A-85, 3% for A-86, < 1% for B-85 and 4% for B-86 (Table 2). Due to the limitations of these techniques this is likely to be a slight underestimate. Percentages are based on the following counts of poles in each of the four categories of poles examined: 265 A-85, 271 A-86, 222 B-85 and 80 B-86. Similar figures were obtained for external decay via the pick test: 3% for A-85, 5% for A-86, < 1 for B-85 and 3% for B-86. These pick test results should however be treated with some caution since they could relate either to pre-treatment basidiomycete decay or post-treatment soft rot.

Mycological Examination of Cores

Viable basidiomycetes were cultured from 16% of A-85 poles, 10% of A-86 poles, 5% of B-85 poles and 3% of B-86. However two thirds of all these isolations consisted of the non-wood-rotting basidiomycete *Sistotrema brinkmannii* aggr. (Bres.) J. Erikss (see discussion below). Excluding *S. brinkmannii*, these percentages were 3% of A-85s, 3% of A-86s, 1% of B-85s and 0% of B-86s (Table 2).

With regard to the position from which the basidiomycetes were isolated, the majority of *S. brinkmannii* isolations came from the above-ground sample while other basidiomycetes were more evenly distributed above and below ground.

The other basidiomycetes have not yet been identified, however four isolates of *Antrodia spp.* and one isolate of *Schizophyllum commune* Fr. were obtained from A-85 poles examined in a previous investigation but not included in this particular

study.

Microscopic Examination of Cores

A total of 843 cores (core #3) were examined microscopically. Only seven poles (<1%) had a biodeterioration ranking, of 2 or greater (Table 2). Soft rot was observed in 3 poles and white-rot in only one. Both were confined to outer core sections. No examples of brown rot or bacterial decay were observed but three cases of decay could not be readily classified.

Examination of Decay Patterns

The extent of decay in the poles examined ranged from none through small patches of intermediate decay to complete destruction of almost the full cross section accompanied by failure in service.

Thirteen of the twenty-five poles examined had intermediate or advanced stages of decay. The remaining twelve poles had early stages of decay or no visually detectable decay. Twenty of the twenty-five poles, including all 13 decayed poles, were from supplier A, three were from supplier B and two were of unknown origin.

Having given these numbers it should be stressed that no conclusions should be drawn from them. They are not a representative sample of any one part of the pole population. The results of this work consisted of patterns of decay rather than numerical evaluations they are therefore described in the discussion section. Interestingly, two of these poles had fruitbodies of *Gloeophyllum sepiarium* (Wulf. : Fr.) Karst. growing from checks. Other discarded segments of similar poles not involved in this study also had fruitbodies of this fungus.

Discussion

The incidence of decay and the role of *S. Brinkmannii*

The best available estimate of the incidence of internal decay in these poles was, 4% of A-85s, 3% of A-86s, <1% of B-85s and 4% of B-86s. This estimate came from the physical inspection of poles in service and is in very good agreement with the mycological data excluding *S. brinkmannii* (except for B-86 where the number of poles sampled was comparatively small). Certainly the premature decay problem is not confined to A-85 poles although it is most prevalent in this group. The one result which does not appear to fit into the pattern is the high incidence of internal decay found by physical inspection in B-86 poles. These findings should be re-evaluated before conclusions are drawn on this set of poles.

The degree to which this pole population is at risk from further failures hinges on whether or not *S. brinkmannii* is capable of causing decay of wood. The answer to this question requires a critical review of the literature. Before considering this question, it is necessary to define our nomenclature.

The name *S. brinkmannii,* as used here, covers an aggregate of species that have not been clearly delimited taxonomically although Hallenburg (13) has attempted to separate the genus into six new species. The *S. brinkmannii* aggregate is easily distinguished by the production of bulbils (clumps or chains of swollen cells linked by clamp connections). It is commonly isolated from sound and decaying wood and has been found in Europe, Australasia and North America. In North America it is found from Arizona to Quebec (13) and from Washington state to New Brunswick (5).

Whether this fungus causes brown-rot (34), white-rot (9, 10) or is saprophytic on decayed wood, soil or other fungi (7) is not clear from the literature. Although this fungus is listed as a wood-rotting fungus by some textbooks this has often been concluded simply because it is a basidiomycete and it has been found in rotted wood. Most documented attempts to test the decay capability of this fungus have failed to show any weight loss in laboratory tests under a variety of conditions (2, 22, 28). The only evidence of very limited weight loss comes from one study (15) using a soil burial test and an extended exposure time. This suggests that, if it can cause decay, *S. brinkmannii* may be a very slow white-rot fungus. An alternative explanation is that the soil in this test may not have been entirely free from contamination by soft-rot fungi.

Certainly *S. brinkmannii* is a component of the microflora colonising air seasoning poles. Morrell *et al.* (20) isolated *S. brinkmannii* from 19% of air seasoning Douglas-fir poles after 7 - 12 months exposure rising to a maximum frequency of 21% after 2 years exposure. It was classified as a 'moderate decayer' on the basis of text book descriptions (19). Carey (1) showed that *S. brinkmannii* can be a primary coloniser of wood and stated (3) that it is a non-wood-rotting basidiomycete. Morris (22) later found, that it can also be a secondary coloniser of decayed wood comparable to the secondary moulds as defined by Clubbe (6).

In a study of in-service utility poles in the eastern United States, Zabel et al. (36) found *Sistotrema spp.* to be among the most common fungi isolated from southern pine poles. They were found more frequently in 37-52 year old poles than in those under 18 years of age and appeared to be associated with checks or defects on the pole surface. The high incidence of *S. brinkmannii* in the poles in the present study, 14% of A-85s, may be due to secondary colonisation of wood decayed by other fungi. The presence of *S. brinkmannii* does not, therefore, necessarily cause, or result from, the presence of decay. The worst case scenario, on the basis of present information, is that *S.*

brinkmannii may be a very slow white-rot fungus. If so, it is still not the major cause of the preservative failure due to brown-rot noted to date. Nevertheless, the much higher incidence of *S. brinkmannii* in the A-85s compared to the other three groups indicates some difference in the handling or treatment of this group of poles possibly related to inadequate sterilization prior to or during treatment.

The microscopic examination of thin sections from cores revealed a very low incidence of 'moderate decay' (rating level 2) or worse, < 1% of all the poles examined. That this figure was lower than the incidence of basidiomycetes can be ascribed to three factors, first the location of the core sample for microscopy, second the numbers of positions sampled using the two methods and third the amount of wood used from the core for each method. With regard to the first factor, the microscope sample was taken from below groundline, a region commonly found to be well treated via end-grain penetration. Decay would not have been able to proceed rapidly, if at all, in this region after treatment. The second and third factors, mentioned above, concern the low probability of locating decayed wood in three thin sections compared to the higher probability of finding a viable fungus in two whole cores.

The type of decay found under the microscope in three of the seven poles with moderate decay was not caused by wood-rotting basidiomycetes but by a group of unrelated fungi, the soft-rot fungi. This soft-rot should be considered as a separate issue from internal decay by wood-rotting basidiomycetes. Since it was only found on three poles, it is possible that this was an unusual occurrence related to localised soil conditions. Nevertheless soft-rot of PCP treated southern pine poles is normally a very slow process (16, 21). For soft-rot to have, progressed to this stage in five to six years the preservative must have had very little effect on the rate of decay.

Previous studies including PCP-treated southern pine poles (4, 36) have not provided comparable data on the incidence of internal decay. However, the latter study showed that white-rot fungi were the dominant cause of decay in such poles towards the end of their normal service life. This does not fit with the finding that the A-85 poles which failed in service were decayed by brown-rot fungi. This suggests that these poles do not fit the normal pattern for well treated penta poles. Zabel, Kenderes and Lombard (35) found decay in 14% of penta-treated Douglas fir poles between zero and ten years in service but these were mainly found in the untreated heartwood of the poles. In southern pine most of the pole volume is treatable sapwood thus there should be no opportunity for survival of basidiomycetes in this zone after treatment. The presence of viable basidiomycetes in the sapwood of these poles such a short time after treatment is one indication that the premature failures have been due to pretreatment infection.

The Evidence for Pretreatment Infection

The characteristics of the decayed poles which have been intensively examined were entirely consistent with pretreatment infection by wood-rotting fungi which survived the treatment process and proceeded to decay untreated wood when the poles were put into service. We will discuss the evidence for pretreatment infection before considering the proposition that the majority of decay, and therefore strength loss occurred in service.

The hypothesis that pretreatment infection was the root cause of the decay was based on the location of decay within the poles, the pattern of decay, the stage of decay reached after five to six years in service and the presence of decay pockets penetrated by oil. The location of most decay appeared to be related to the pattern of drying of the pole during air seasoning rather than to the pattern of rewetting in service. The most extensive decay in poles in service normally occurs at the groundline (12, 14, 24), in contrast pretreatment infection can occur along most of the length of the pole (17, 23, 27, 37).

In ten of the twelve poles with intermediate or advanced decay which were intensively examined, the greatest damage had occurred in the middle of the length of the pole (Figures 2 and 3). This section would be the last to dry out in the wide sapwood southern pine species, since drying through the end grain can be 1000 to 10000 times faster than through the sides. Similarly, where the decay was less extensive it was commonly confined to the inner sapwood, the last part of the cross section to dry out. Although inner sapwood decay can be caused by post treatment infection of a band of untreated sapwood via checks (24), this is extremely unlikely in such a wide sapwood treatable species. There was no evidence of checks developing after treatment penetrating the full depth of the sapwood and the decay patterns were not associated with checks.

Unlike the situation of post-treatment infection the locations of the decay pockets above ground in the poles examined were mostly unrelated to bolt holes, wood pecker holes, checks or other access points for water and fungi to get through the treated zone. Having said this, in some poles decay had only progressed to the advanced stage where water could have entered the pole after treatment, near the groundline or near bolt holes, but the rest of the pole did show intermediate stages of decay. This suggests that the pole had dried down sufficiently to slow the decay over most of the length and decay had only proceeded rapidly where the pole had rewetted in service.

The patterns of decay were related to the pattern of infection and colonisation of poles by fungi during air seasoning. This was most discernable where the decay had not progressed too far. Here the decay pattern consisted of a collection of roughly wedge shaped segments radiating out from the heartwood (Figure 2). In most cases the decay did not reach

the surface of the pole presumably due to early drying of the outer sapwood. Wedge shaped segments are the result of the typical colonisation pattern of fungi in unseasoned roundwood. This is controlled by the wood anatomy (30), moisture distribution and competition between fungi.

Very often the segments colonised by the wood-rotting fungi can not be penetrated by oilborne preservatives during the pressure treatment process. This is because oil does not readily penetrate wet wood. The segments colonised may be those which remained wet during air seasoning. Alternatively the action of decay may also have caused the wood to remain wet in two ways. First, breakdown of the wood carbohydrate produces carbon dioxide and water. Second, an increase in the permeability of the wood makes it more likely to soak up water during periods of rain. Wood-rotting fungi are only active at moisture contents above about 25% and are at their most active at between 40 and 100% moisture content. Oilborne preservatives do not penetrate wood very well at moisture contents above 25%. The wood-rotting fungi can therefore survive in untreated segments later causing decay of this untreated wood. As a result the pattern of treatment is controlled by the pattern of decay and not vice versa as would be the case with post treatment decay.

The presence of apparently high loadings of oil in voids created by decay suggested that some advanced decay had occurred prior to pressure treatment. The distribution of oil in the decayed wood was too even to have been due to movement of oil after treatment.

The advanced stage of decay reached in such a short time in service was a further indication that this decay resulted from pretreatment infection. Eight poles showed intermediate or advanced decay over virtually the full cross section and over most of the length of the pole (Figure 3). For this to have occurred over five or six years, the pole must have been at a suitable moisture content for decay since the time the pole went in to service and the pole must have been treated to a relatively shallow depth. This shallow penetration could have been caused by an inadequate vacuum-pressure schedule or by a high moisture content at the time of treatment. In addition one of the following two scenarios must have occurred. Either the pole was infected at a large number of points soon after treatment or it was already infected prior to treatment. The latter scenario is by far the most plausible. The presence of intermediate or advanced decay in the heartwood of three poles also suggested that the decay had been in progress for some considerable time because the heartwood of most southern pine species is moderately durable and therefore decays much more slowly than the sapwood.

The proposition that, although infection occurred prior to treatment, much of the decay occurred in service was based on two observations. First the advanced state of decay of the poles which failed in service or broke during extraction for this

study. This degree of decay, if present at the time of installation, would have been readily noted by the line crews and these poles would have been discarded at that time. Second, on some poles, the progress of decay from the intermediate to the advanced stage had been prevented or limited in scope by the presence of preservative. This was particularly exemplified by two poles in which, within wedge-shaped segments of pretreatment infection, the more permeable late wood had remained sound while the early-wood decayed. This can be explained by the known pattern of penetration of oilborne preservatives into wood. The late-wood is more permeable to preservatives than the early-wood (11) thus preservative could have penetrated only the late-wood within the segment colonised by the wood-rotting fungus killing the fungus and preventing decay in the late-wood but allowing decay to proceed in the early-wood. Other examples were seen where decay had been stopped by the treatment; particularly near the ends of the poles where the poles had dried out and had subsequently been well treated via the end-grain.

Pretreatment infection and decay in southern pine poles should come as no surprise to the treating industry. Panek (26) noted that "Air seasoning, even for brief periods of a few weeks, often is accompanied by infection from mould, stain and decay fungi which can seriously impair the value of the poles and piles if not diminish their strength properties." Mills *et. al.* (18) reported that southern pine poles, which had been air seasoned very carefully, showed, incipient decay in 56% of poles after three months under a shed. Taylor (32) described pretreatment decay as a 'chronic problem that plagues the utility industry in their poles which they purchase from the wood preserving industry'. He cited numerous references on the subject but many of these were anecdotal and were dismissed as unsubstantiated by the industry in the discussion of the paper at the American Wood Preservers Association annual meeting. Taylor (32) recommended the reduction or elimination of air seasoning and the sterilisation of poles by heat treatment. Taylor again raised concerns about pretreatment decay in 1985 and proposed the universal adoption of kiln drying as a means of solving the problem (33). Despite this history, it is extremely unlikely that the decayed poles dated 1985, examined in this study, had been kiln dried. Since 1985, kiln drying of southern pine poles has become common practice thus the problems described here would not be expected to occur in more recently installed poles.

Conclusions

The incidence of decay in A-85 poles was 4% based on physical and mycological examination of core samples and the contention that *S. brinkmannii* is not a wood-rotting fungus.

On the same basis the incidences of decay in A-86 and B-85 poles were 3% and less than 1% respectively.

The incidence of decay in B-86 poles cannot be reliably determined at this time.

The cause of the premature failures was pretreatment infection and decay which continued to cause further strength loss in service.

At least 3% of A-85s could continue to decay unless there is sufficient preservative penetration and retention to prevent this.

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Table 1. Rating scheme for microscopic observation of core samples.

Ranking of biodeterioration	Microscopic Observations
0	Sound, no evidence of biodeterioration.
1	Evidence of microbial damage, typically rays and/or bordered pits lightly attacked but tracheid walls sound.
2	Moderate number of decay features, rays and/or bordered pits attacked and evidence of deterioration in tracheid walls, may include bore holes, erosion troughs, soft-rot cavities or some loss of birefringence.
3	Large number of decay features, rays very deteriorated, tracheids exhibit large areas of erosion, many soft-rot cavities, or loss of birefringence, many pits damaged.
4	Rays and tracheids very highly deteriorated almost complete loss of birefringence.

Table 2. Incidence Of Decay (% of Poles) Observed With Physical Inspection (Hammer and Pick Test) Microscopic Examination and Mycological Assay. Percent of Poles Showing Decay.

	PHYSICAL		MICROSCOPIC*		MYCOLOGICAL	
	INTERNAL	EXTERNAL	INTERNAL	EXTERNAL	ALL ISOLATES	EXCLUDING *S. brinkmannii*
	N=46(5%)		N=7(<1%)		N=84(10%)	
A-85	4	3	<1	<1	16	3
A-86	3	5	<1	0	10	3
B-85	<1	<1	<1	0	5	1
B-86	4	3	0	0	3	0

* Rating of 2 or more excluding soft-rot.

FIGURE 2

Extent of Decay in Pole #W237 Over Cross Sections at 1 m Intervals

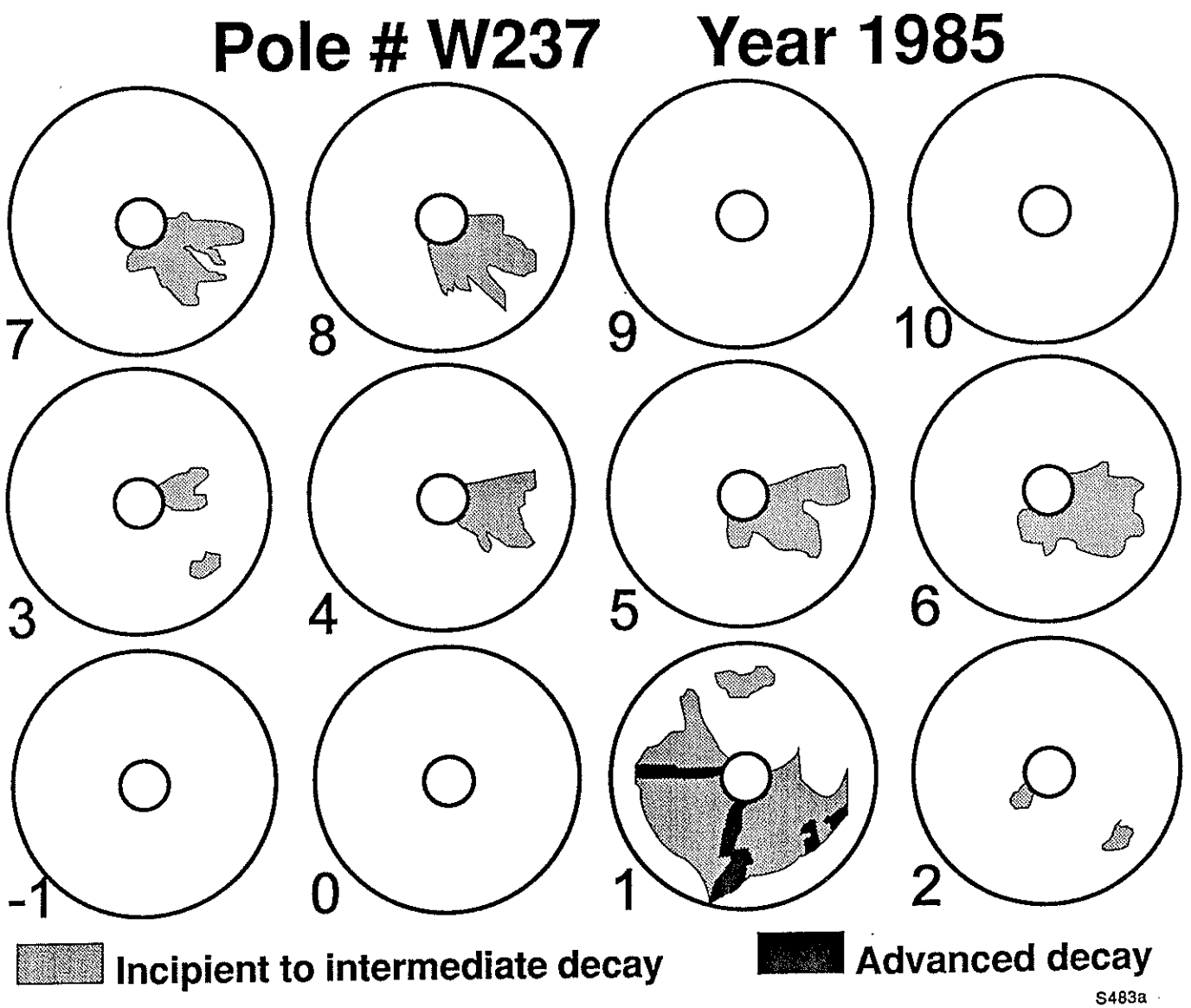

FIGURE 3

Extent of Decay in Pole #D641 Over Cross Sections at 1 m Intervals

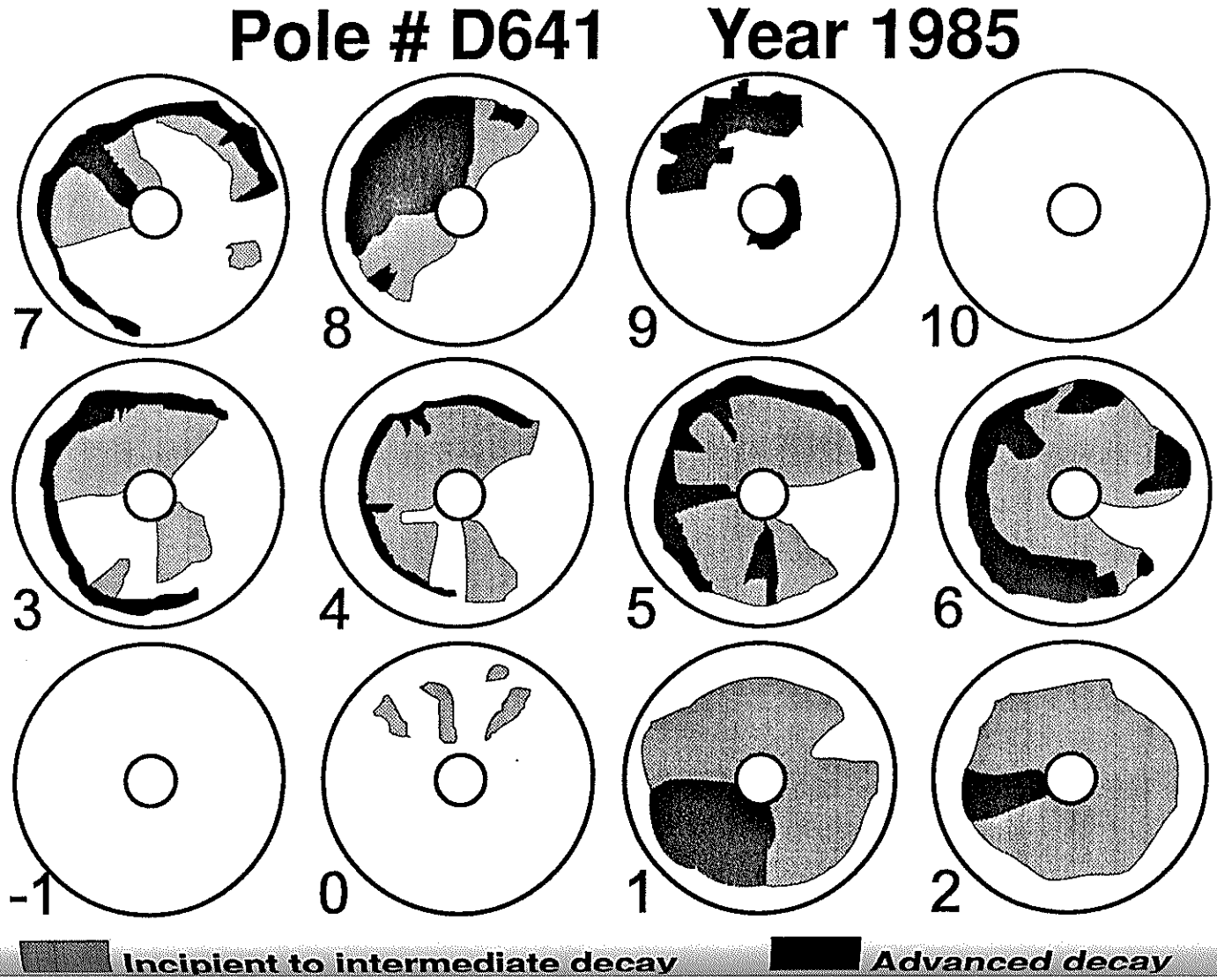

FIGURE 1

Core Sample Positions for Survey of Poles In Service