

A HISTORY OF PLOUGH DEVELOPMENT IN BRITISH FORESTRY

III. HISTORICAL REVIEW OF PLOUGHING ON DRIER SOILS

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The history of ploughing on the drier soils is, as Zehetmayr described it in 1960, a complicated story. On the heaths where the main development took place, the treatment has had as main objectives the breaking of a superficial shallow peaty layer, the reduction of early vegetation competition, and the disruption and aeration of deeper compact soil horizons to allow better root penetration and development.

Silviculturally, early tree growth was soon seen to respond to each of the above aspects of cultivation, but only in more recent years have the benefits of deeper cultivation been appreciated in terms of longevity of treatment response. (Thomson and Neustein, 1973).

Mechanically, four main phases were distinguished by Zehetmayr (1960) and these are well illustrated in Figure 1 (from FC Bull. 32, p. 41) namely:—

1. Shallow ploughing (4-7 inches deep) with agricultural ploughs using horses or wheeled tractors.
2. Moderately deep ploughing (8-11 inches) with strengthened agricultural ploughs and light crawler tractors. Subsoiling was latterly combined.
3. Deep ploughing (12-16 inches) with specially built forest ploughs.
4. Tine ploughing in which the addition of a robust sub-soiler attached to somewhat shallower ploughs combined deep disruption with the benefits obtained by more superficial cultivation.

A fifth phase could now be added, namely very deep (complete) ploughing (17-30 inches). This has arisen from an increased awareness of the extent and nature of indurated soils with a consequent move towards more intensive cultivation. Thus although new standard techniques have not yet become widely established, deep complete cultivation is becoming more prevalent at the compact end of the heathland continuum. The large ploughs and heavy tractors required are considered to be silviculturally preferable to lighter tine ploughs, but the lack of firm experimental evidence of sufficient age still weakens the resolve of some managers to commit themselves to the higher costs involved.

In contrast to the situation on the wet soils, the use of Sitka spruce has always been heavily dependent on the type of cultivation, and each change in method reinforced the hope that this potentially productive species could be used on heaths which traditionally have been regarded as more suitable for less moisture demanding and less heather sensitive

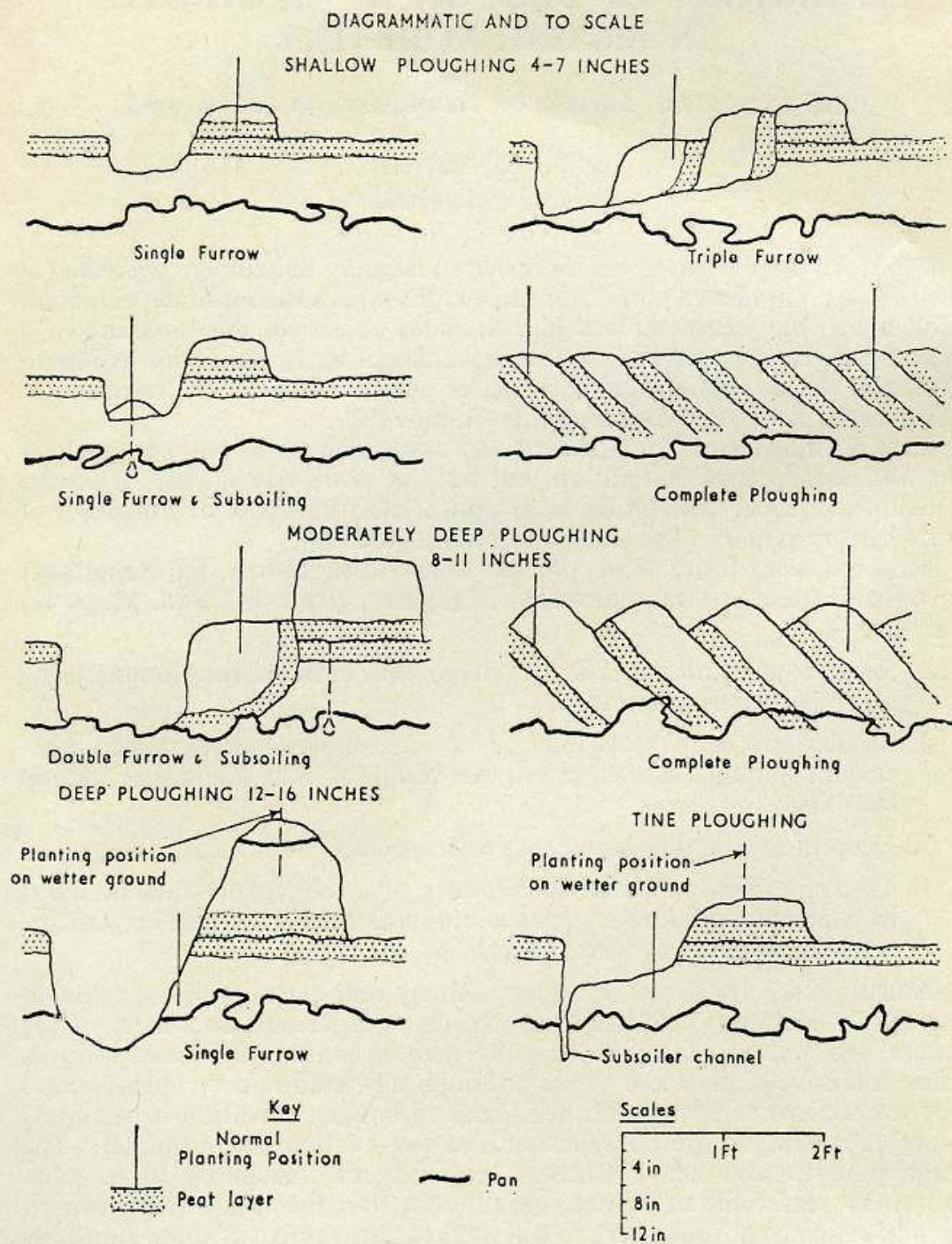


Fig. 1
Types of ploughing used on the heaths

species. Even now it is not clear to what extent the growth response of Sitka spruce to a given intensity of cultivation is a reflection of *Calluna* suppression or to real long term improvements in the physical soil conditions. Lord Robinson in a departmental paper commented after the first successful trial of the single furrow Solotrac at Allerston "neither I nor anybody else anticipated the vigorous development of the stunted heather which follows ploughing . . . and we were puzzled to know what to plant."

The first recorded ploughing of heathland by the Forestry Commission was in Yorkshire at Staindale quite near to the area where six-horse ploughing for afforestation had been carried out in 1869. The plough used here in 1922 was of light agricultural type towed by a wheeled Fordson tractor. Spruce was planted but checked within a few years and the area was ultimately replanted. In 1924 similar equipment was again used (Staindale Experiment 1) on an area which had been burnt over but nevertheless the plough did little more than skim off some three inches of wet peat.

In the main Scottish heathland experimental area at Teindland in Morayshire the first ploughing took place in 1926 when a two-horse agricultural plough was used at two different furrow spacings and a sub-soiler, also drawn by two horses was thereafter used on some of the ploughed furrows. In 1927/28 at the instigation of M. L. Anderson, the Scottish Research Officer, two similar specially designed ploughs of normal agricultural configuration but having twice the normal weight, were built at the Standfast Works at Craigellachie and these, pulled by two or three horses, were used in a succession of experiments between 1928 and 1935 at Teindland and at Clashindarroch (Experiment 5, 6 and 7) (see part I, Pl. 1). These ploughs, and possibly the horses, failed where peat depth exceeded four inches (*e.g.* when tried at Inchnacardoch) but on drier areas merchantable crops were produced. Apart from a visit by the Henderson plough in the mid 1930s and a hired tractor-drawn agricultural model (the "Sungrade" used in 1937 in Experiment 62, etc.) no further experimental ploughing was done at Teindland until after the War. Experimental work at Teindland had included single furrow, double furrow, triple furrow and complete ploughing but Zehetmayr states that there was no large scale use of ploughs on Scottish heaths until 1937 when the results of developments in Yorkshire were introduced.

In S.E. England on chalk downland a horse-drawn agricultural Ransome plough was used at Friston Forest in 1927, to produce furrows spaced at $4\frac{1}{2}$ feet. Wood (1962) describes the succeeding developments on this soil type for which shallow ploughing was peculiarly appropriate.

The 1930s were a period of lively development in north east England. Enthusiastic staff worked closely together to evolve practical equipment which was simultaneously utilised by field staff and incorporated in comparative experiments at the Allerston (Wykeham) Experimental Reserve. The personal interest of Lord Robinson (then the Forestry Commission's Chairman), and the early growth responses obtained in carefully laid out experiments maintained a momentum of development

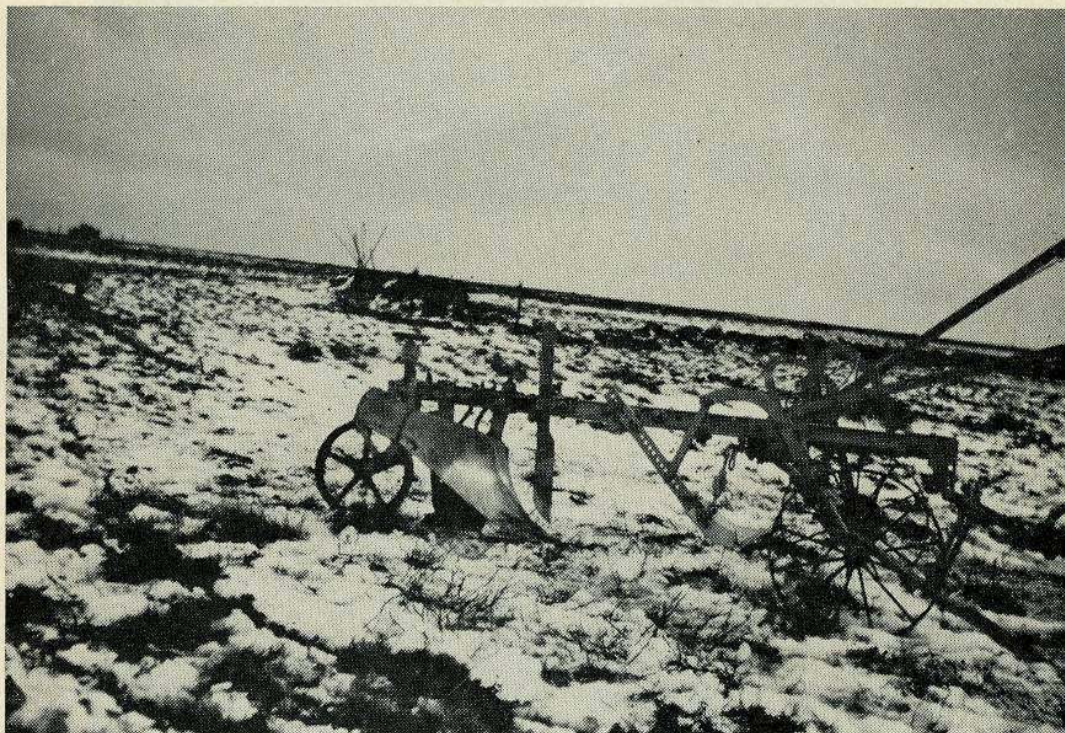
which culminated in 1942 in the RLR plough named after Lord Robinson himself.

In 1929 wheeled Fordson tractors towing single furrow ploughs fitted with sub-soilers were in conservancy use on relatively easy (podzolic) ground and depths of up to eight inches were reached, but on harder ground this decreased to 3-4 inches. A. H. Ross (1931) who was at that time a local District Officer, records that under such conditions the pan was never touched and that moreover the wear and tear on tractors and implements was such that by degrees the moor became littered with broken pieces of machinery and derelict tractor wheels. Early in 1930, using a Caterpillar 20 (approximately equivalent to the later D2 model) a trial of various Ransome agricultural ploughs was carried out at Staindale: the single furrow "Unitrac" (Pl. 1), the double furrow "Deeptrac," a three-disc plough, and a sub-soiler "Killifer" (Pl. 2). The latter consisted of a strong carriage on two large wheels carrying a robust vertical blade which had a steel chisel point designed to reach a maximum depth of 20 inches. The passage of the implement produced a strong heaving action with soil lifting up to two feet on either side of the central blade. The sub-soiler proved useful when preceding the plough to relieve compaction and enable the plough to reach full depth or when following in the plough furrow to deepen the achieved disruption and loosen the favoured planting spot in the furrow.

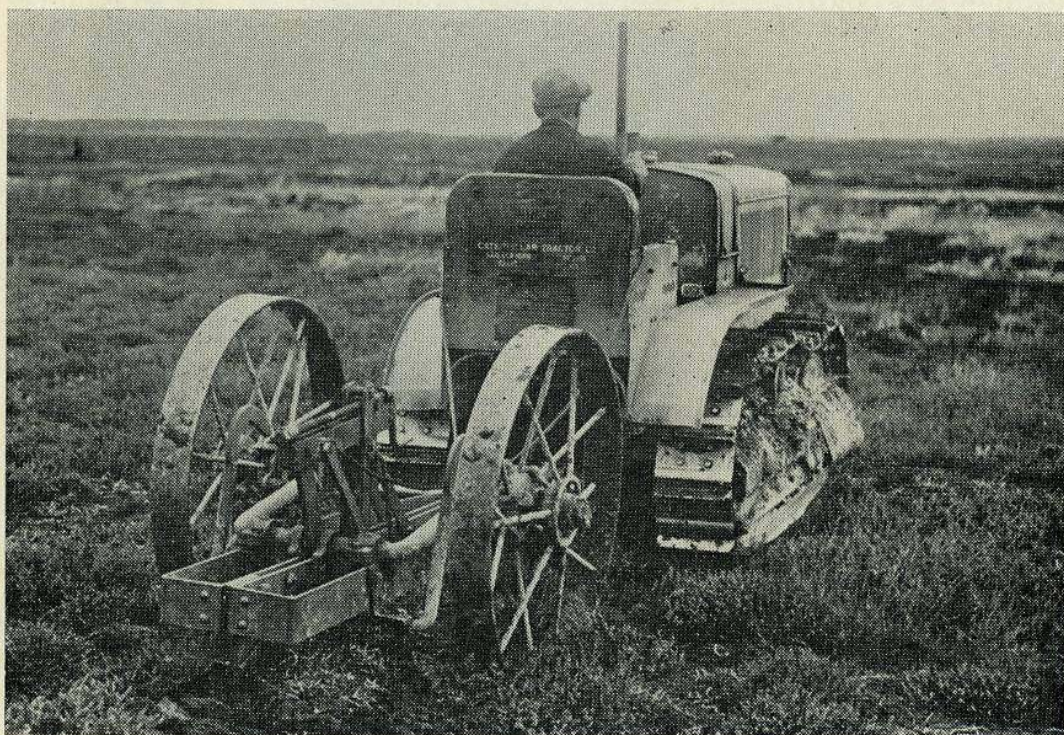
Lord Robinson attended this trial in which the Caterpillar 20 crawler tractor had demonstrated a real breakthrough in feasibility, and concluded a few weeks later that "from these experimental beginnings ploughing will now be commenced on a commercial scale at Allerston where a stretch of nearly 1000 acres awaits treatment." (Robinson, 1930).

Later it became standard practice for the sub-soiler to follow in the plough furrow until the RLR plough supplemented this combination treatment. The disc plough (Pl. 3) was found unsuitable but the other ploughs attained furrow depths of 10 inches and 12 inches respectively.

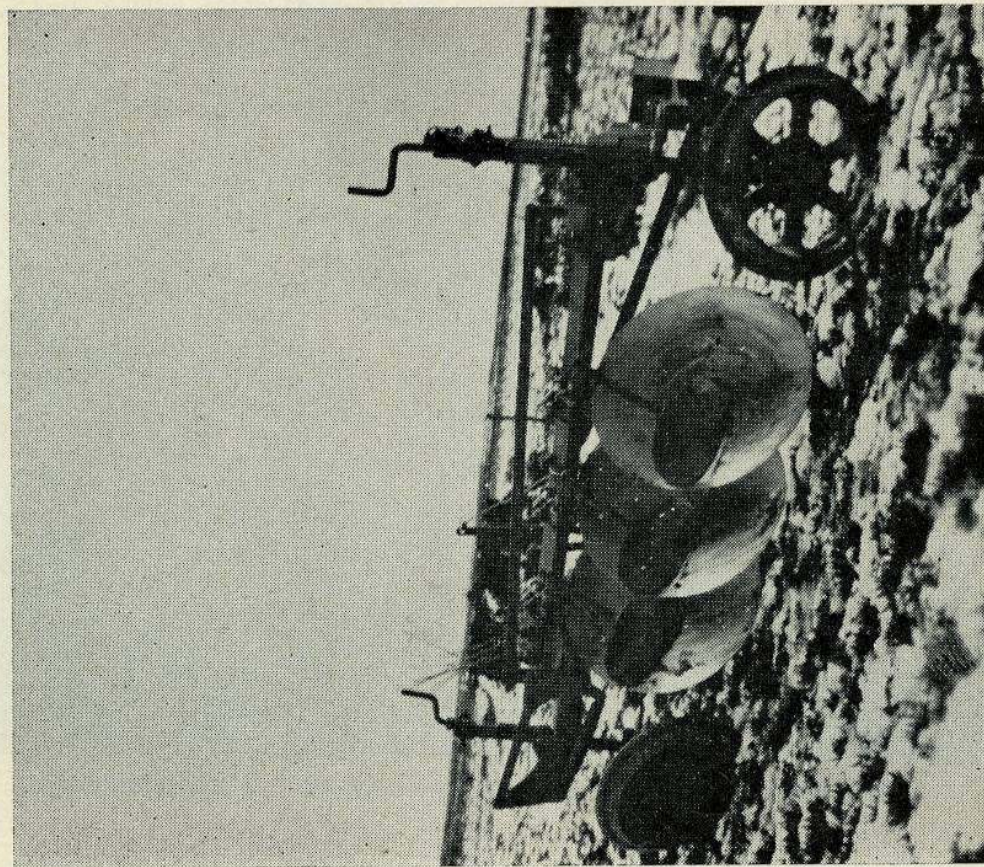
A year later A. H. Ross (1931) could claim encouraging experience and describe modifications to this equipment *e.g.* strengthening of the plough beams to cope with the stresses of crawler traction and manganese-hardened points for the sub-soiler. In addition an Oliver double furrow plough was purchased whose main advantages were relative lightness and heat-strengthened beams which were somewhat less prone to bending; but even these had to be strengthened in due course by bolting on a second beam (Pl. 4). These agricultural ploughs were all designed for normal complete ploughing where the furrow-side wheel normally runs in the furrow, whereas in spaced furrow or strip ploughing this wheel had to run on unploughed land. Thus when set at its maximum depth, the plough travelled on an uneven keel. This feature was remedied by extending the axle of the Oliver plough's furrow-side wheel so as to allow the wheel to run in the land side furrow of the adjacent strip, and in the Ransome ploughs by fitting a special attachment. There was much debate at this time about the virtues of bringing up unweathered sub-soil to the surface as opposed to sub-soiling, the virtues of double furrow plough-



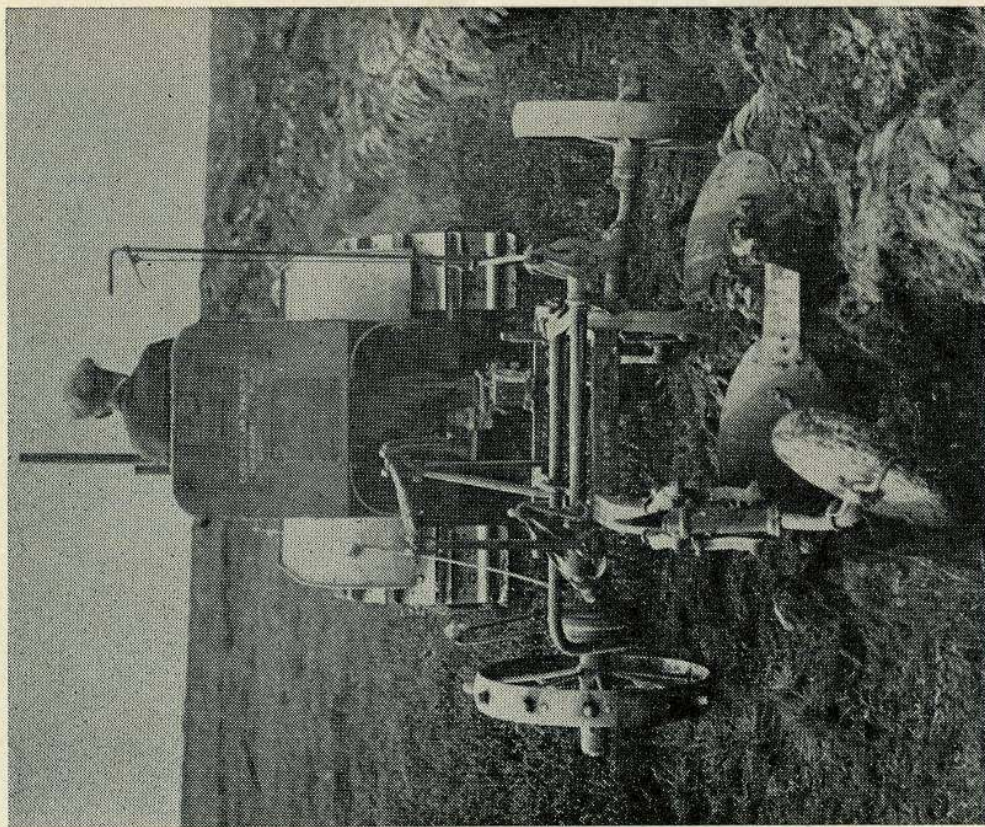
Pl. 1. Ransom deep single furrow plough. (Forestry Commission F265).



Pl. 2. Ransom subsoiler pulled by a Caterpillar 20. (Forestry Commission C912).



Pl. 3. The unsuccessful Ransom three-disc plough, Allerston 1930.
(Forestry Commission F268).



Pl. 4. Oliver two-furrow plough pulled by a Caterpillar 20.
(Forestry Commission C9111).

ing as opposed to deeper single furrow ploughing, and the debate was to continue for the next 20 years as later developments favoured opposing aspects of these choices.

These ploughs soon became widely used, *e.g.* on the Dorset Heaths where more than 200 acres were ploughed in 1931 and 1932 (Colwill, 1933) and in total the two Caterpillar 20s ploughed 2800 acres in all parts of England at a rate ranging from $1\frac{1}{2}$ - $4\frac{3}{4}$ hours per acre. Costs and standards overall compared favourably with handwork (Honeywill, 1934). Forestry Commission Silviculture Circular No. 12 (1933) records that this equipment was used at Wareham, Thetford, Ringwood, Ferndown, Clipstone, Delamere, Wilsey Down and Crechfa—on a small proportion of this area the sub-soiler only was used.

Zehetmayr (1960) describes the use and results of these ploughs in silvicultural experiments. Studies of tree root responses to the new treatments were first reported by Fossey (1934) and the amount of variation found on apparently uniform ground evenly ploughed was later again reflected by Rennie (1953) and in the tree pulling studies of the 1960s.

The mid and late 1930s in north east England saw much use of the moderately deep single furrow Solotrac (Pl. 5) and Oliver ploughs with Killifer sub-soilers but towards the end of the decade there was some loss in confidence in the potential of this equipment. Anderson (1938) describes the particular problems associated with delayed planting of ploughed areas. As can be seen from the illustrations, the ploughs were not really strongly constructed and repairs were constantly required in spite of their being "nursed" by shallow passage. (Weatherell, personal communication). The depth achieved by the plough in normal practice rarely exceeded six inches and the amount of spoil was not sufficient to prevent the re-colonisation of invigorated heather. Because of this the use of spruce was curtailed to some extent (Cons. Annual Rep., 1934). By 1942 large areas of spruce (often in admixture with Scots pine) were in "check" and planting programmes were consequently reduced in Yorkshire.

In 1936 Lord Robinson on a northern tour was so impressed with early results of ploughing in Yorkshire that later on the same trip he personally negotiated to purchase the first 1400 acres of Millbuie and in 1937 between May and October approved the acquisition of a further 5500 acres in seven separate lots (at an average price of £2/acre).

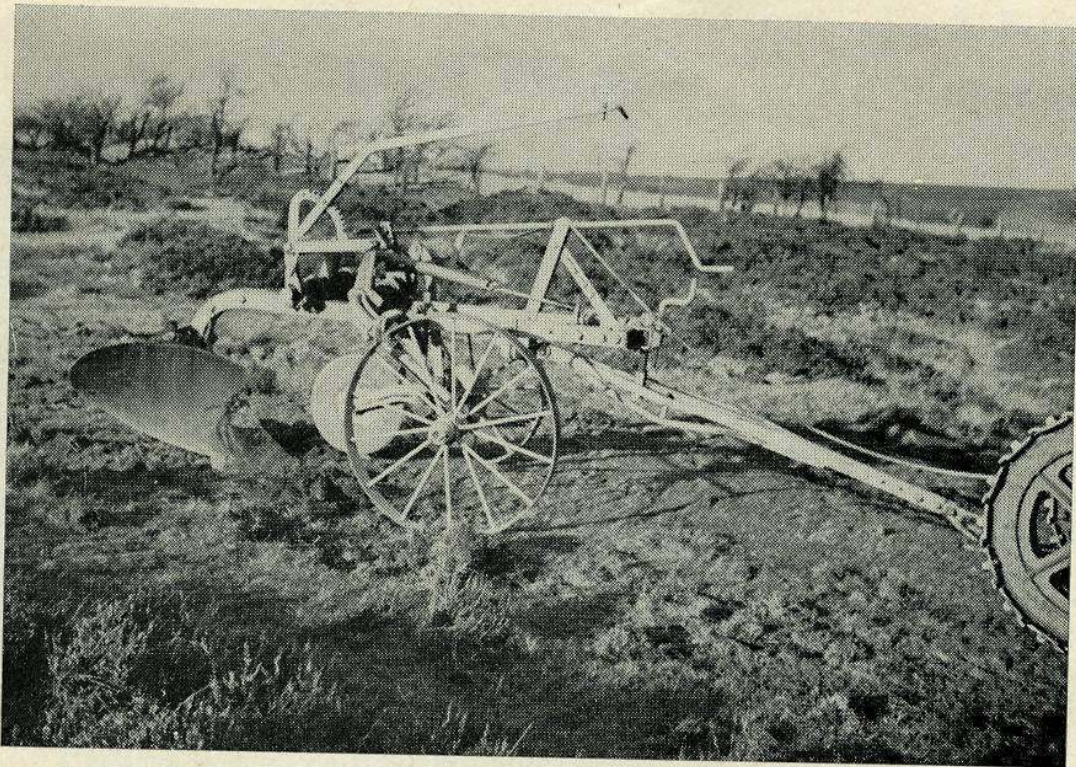
Ransome Major Unitrac and Duotrac (Pl. 6) ploughs drawn by a Caterpillar 20 (or 22) were first tried in north Scotland at Findon Forest (Black Isle) in 1937. Repairs and modifications were made by Messrs Mackenzie of Evanton. (Oliver, personal communication). In south Scotland new Ransome ploughs were first sent to Charles Morrison, an agricultural engineer in Haddington who virtually dismantled them before strengthening them with laminated plough beams etc. Then, under the name of Morrison or Haddington ploughs they were widely used on the heaths of north and east Scotland. (Blane, personal communication). In 1956 the Scottish East Conservancy's report refers to their use on ex-agricultural land, and Zehetmayr (1956) describes their use as confined to early podzolic heaths and shallow peat (Pl. 7).

In North Wales the conservancy fleet of ploughs in 1953 still included 10 much modified Solotracs (and four twin mouldboard Duotracs used to plough fire traces). Although their usage subsequently decreased, their lightness and the hinged turf were valued in Wales where contour ploughing prevailed on steep intergrade soils, on which only vegetation suppression was aimed at, and the last Solotracs survived until 1965 (N. Wales Cons. Rep.). A "Swamp" plough body was used on moister soils, as opposed to the "Bar-point" model on drier areas (W. M. Low, personal communication).

A particularly comprehensive review of prewar ploughing experience was produced in response to a national questionnaire (Robinson *et al*, 1938).

During the War, with its need to maximise agricultural production, a large number of Canadian Massey Harris Grub-breaker ploughs were imported for land reclamation. These were quite strong and produced a wide though shallow turf about 4-6 inches deep and 20 inches wide. At least three models existed and the name Prairie Buster was used for some. Although Zehetmayr (1960) refers to a double furrow version, the single furrow models were the most prevalent (Blane and Clark, personal communication). An important advantage that this plough had over the Solotracs was a wide clearance between beam and plough ($2\frac{1}{2}$ -3 feet) which together with its greater strength allowed more continuous passage. The single furrow Grub-Breaker was first used at Broxa in 1942 and quite extensively in Scotland at Achnashellach, Millbuie, and Devilla both for afforestation and for fire traces. The lack of replacement parts and the expense of repair led to their obsolescence. After seeing one in use at Broxa, Lord Robinson was inspired to set in motion the development of the first purpose-built Forestry Commission plough. He strongly held the view that "partial ploughing (*i.e.* with spaced furrows) with the soil heaped high is, apart from the cost, superior in the long run to full (*i.e.* complete shallow) ploughing on hard heaths." (Low thought that he feared that complete ploughing would lead to agriculture taking over forestry ground). The local team which produced the so-called RLR plough comprised Dilley (Blane's assistant and later to be designated Cultivations Officer for the English Directorate), A. Paterson (District Officer), J. Weatherall (Research Forester, Allerston) and Messrs Russell of Kirkby Moorside (Agricultural Engineers). Sir Roy Lister, as he was then, took a continuing personal interest and provided the impetus and set the basic specification that a plough depth of 18 inches had to be achieved with a D4 tractor.

The prototype RLR was tested at Broxa in the following year (Pl. 8). It was massive by then current standards, having a mouldboard almost twice as big as that of the Massey Harris Grub-Breaker and it was almost three times as heavy. It was initially essentially a Killifer sub-soiler followed by an enlarged single furrow Oliver. A third rear wheel facilitated coupling in to the tractor. Although it occasionally reached 19 inches depth, more commonly it ranged between 12 inches and 16 inches. It soon superseded the Solotracs in Yorkshire though the latter were still in use



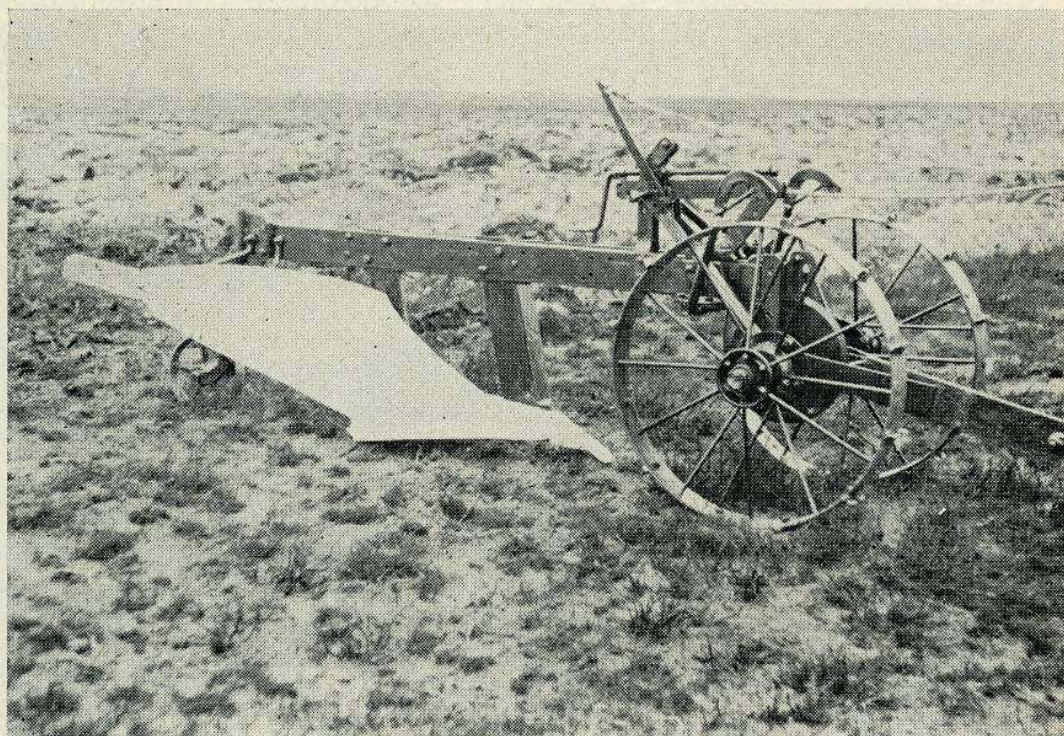
Pl. 5. Ransom Solo-trac single furrow plough. (Forestry Commission B53).



Pl. 6. Ransom two-furrow plough (Two-trac) which incorporated discs. (F.C. F266).



Pl. 7. Solo-trac plough at Speymouth 1952. (Forestry Commission B847).



Pl. 8. Prototype RLR plough. (Forestry Commission C488).

on easier ground and in some regions as already noted. The RLR was widely used experimentally on northern and eastern heaths and became the standard heathland plough on many areas, e.g. in Yorkshire and the Tweed Valley. Early models were made with low grade wartime steel and frequent repairs were required (NE Cons. Annual Rep., 1964). Zehetmayr in the 1950 Research Report noted that there was then no clear tree response to the improved depth of the RLR but nevertheless he supported its adoption, presumably on the basis of its ability to work in rank heather and the easier replacement of worn parts. It was apparently built with removable sections for this purpose. Sargeant (1955) gives a very good description of its operation and maintenance. One important drawback in its design was its lack of manoeuvrability in that it could not easily be reversed. This was often required on stumpy or boulder-strewn ground and generally tougher conditions into which characteristically every new plough was put. In 1953 the NE England Conservancy report noted that repairs were costing more than the ploughing operation and that each tractor had two ploughs associated with it to allow for breakdowns. The cranked axle was a particular weakness. The RLR remained in widespread service until the late 1950s in some areas (Zehetmayr, 1956) though in S(S) it was not used after 1952 (Pl. 9). From 1961 a so-called Allerston Hybrid plough using the excellent RLR mouldboard on a Parkgate carriage was in use for several years.

The decade between the late 1940s and late 1950s was a busy and somewhat confused period in the development of ploughs for the harder heaths. As opposed to the situation on peatlands where Cuthbertson ploughs reigned supreme, foresters on heaths were less content with available equipment and indeed less certain of the effect that they wished to achieve.

Zehetmayr (1960) notes that the difficulties which the RLR and Solotrac were encountering on more stony ground raised doubts about what deep single furrow ploughing was achieving besides pan-breaking, that could not be achieved more easily by sub-soiling. Also good early growth of furrow-planted trees threw further doubt on the need for a high ridge of spoil from deep single furrows. Position of planting remained a debatable topic for many years. (Edwards *et al*, 1963). The difficulties of reconciling depth and intensity in the context of available or adaptable equipment gave rise to a series of prototypes. One ineffective attempt was a Cuthbertson Type F with a small sub-soiler added to the sole-plate. This was used in Teindland Exp. 69, p. 48. Some of these prototypes were successful on limited areas but none prevailed generally.

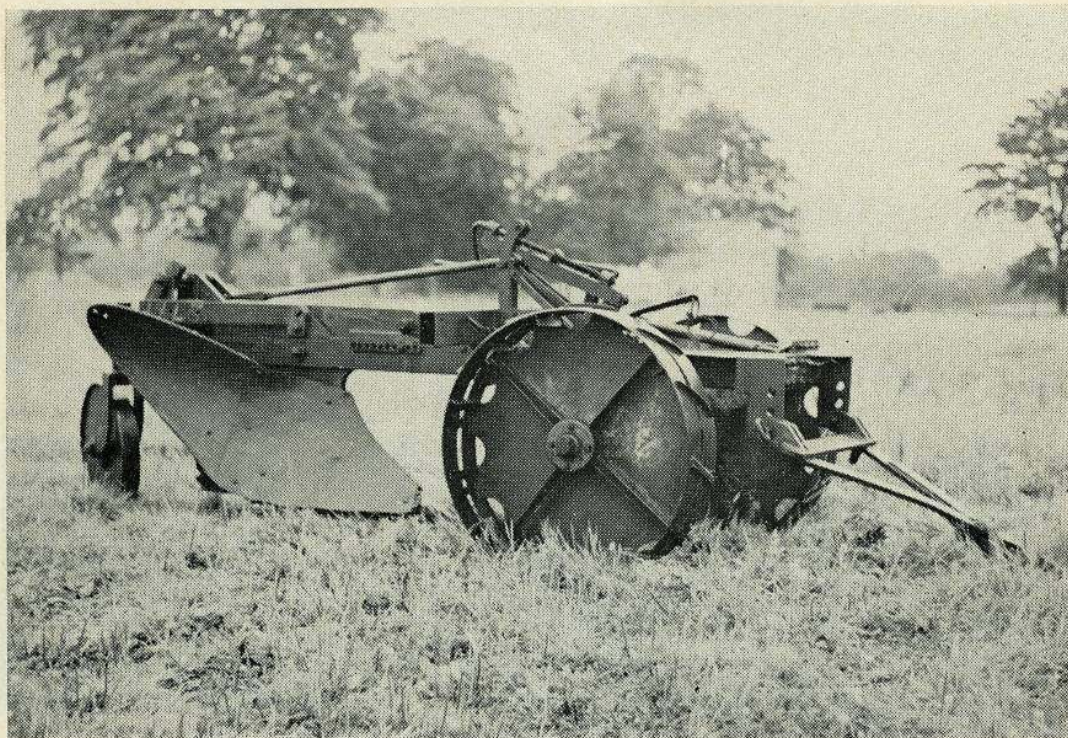
In response to requests for a strong reliable sub-soiler Blane (1950, personal communication) borrowed a Civil Engineering ripper from the naval yards at Rosyth. This consisted of an American frame (produced by the Le Tourneau Company) carried on an International TD18 crawler. On this frame were fitted three (British) Blaw Knox tines—its normal function was breaking up concrete runways. This monster was tried at Keillour forest for two days with sufficient promise to justify the transfer of a single Blaw Knox tine onto a Cuthbertson beam and carriage (by

Clark, Parkgate). This was tried in south Scotland at Brown Moor Forest, and no sooner had its massive shattering capability been demonstrated than Blane was asked to attach a mouldboard to provide a simultaneous planting turf. (A similar series of steps were taken in the late 1960s in the production of the Sickie tine plough). Firstly, a small agricultural Cockshutt mouldboard was welded to the ripper, and soon after an agricultural Ferguson mouldboard was substituted. This equipment did not leave the experimental stage, partly because of the unacceptable power required and partly because the Cuthbertson carriage and beam were neither strong or manoeuvrable enough to cope with the side thrusts encountered on strong compacted soils for which it was intended. However, it introduced the concept of tine ploughing.

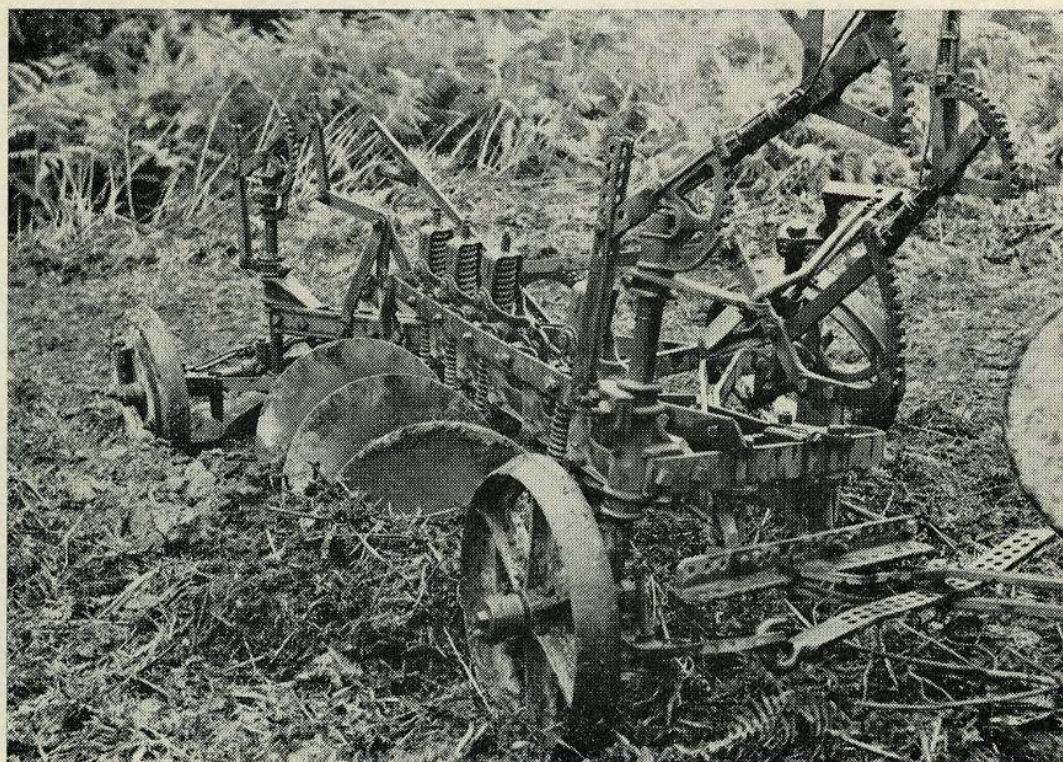
Manoeuvrability was becoming an important feature of heathland ploughing. The long straight runs found at Allerston for which the RLR plough had been well suited were less frequently found on the newer, more difficult, areas. To improve manoeuvrability, Begg mounted one of his ploughs directly on a TD9 crawler by means of a gantry with wire rope control. This was tested at Fetteresso in 1950. Another later attempt was to fit a tine plough on to the tool bar of a Caterpillar D4 but this close coupling could result in the tine being stuck below a boulder on which the tractor itself was sitting and consequently the attempt to lift both plough and tractor simultaneously damaged the tractor. The idea was discarded after little usage in east Scotland.

Another avenue of development during this period followed the root studies carried out by Yeatman between 1951 and 1953. His recommendation was clearly stated (Yeatman, 1955). "The first essential for all upland heaths is a complete cultivation of the surface in order to destroy the continuity of the surface peat and to mix and disturb the mineral soil and peat to some depth. This will also disrupt a large proportion of shallow pan formation. The poorest sites have a relatively shallow (10-16 inches) pan/compact sub-soil, and attendant poor drainage from above the pan, and may require in addition frequent sub-soiling to about 18 inches. Yeatman had convinced a meeting of Conservators in 1953 that the complete cultivation element of this specification could be met by disc ploughs.

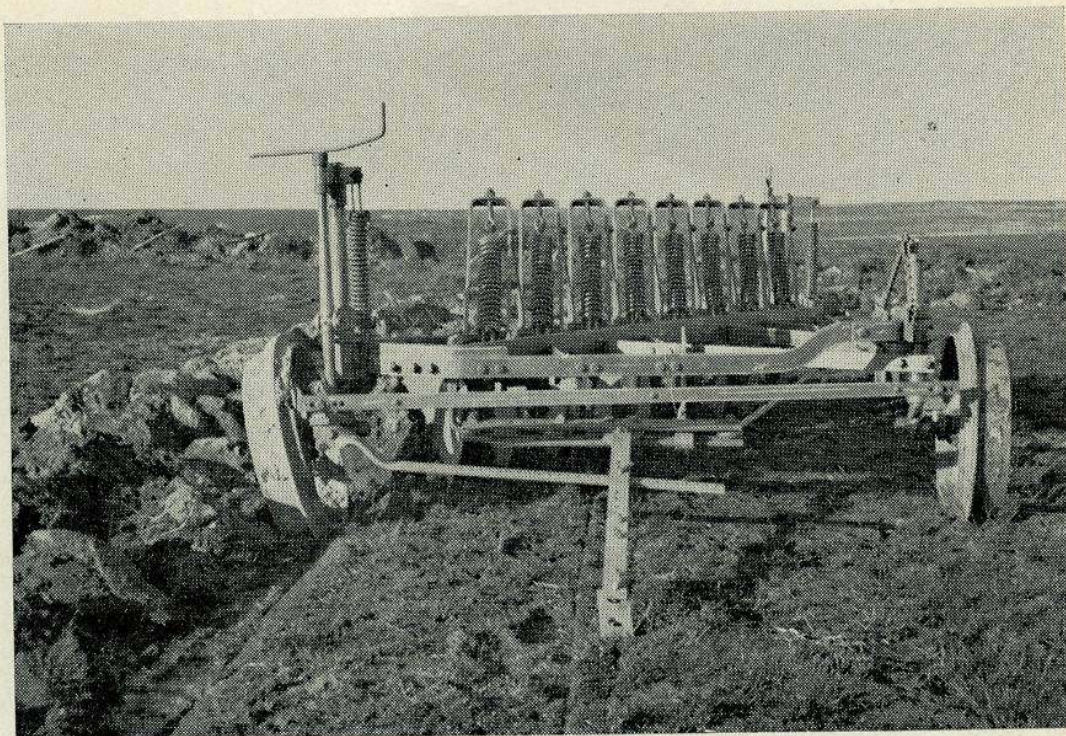
Before disc ploughs were tested, some small scale trials were carried out by sub-soiling with a tine plough from which the mouldboard had been removed, followed by shallow complete ploughing with an agricultural plough. (The Fisher-Humphrey "Bracre"). In an attempt to make this method more economic, preliminary trials were carried out with an agricultural disc plough manufactured by the Newlands Engineering Company of Linlithgow. This mounted tool was fairly light at 10-12 cwt and had three discs but was quite unsatisfactory when tried at Devilla. A larger four-disc plough, known in Forestry Commission circles as the "Sunshine" or "Sun vertical" stump-jump plough was located at the National Institute of Agricultural Engineering Research Station and it was incorporated in an experiment at Devilla (2 p. 53), but this too was not heavy enough (Pl. 10). Both the Fisher Humphries Bracre and this



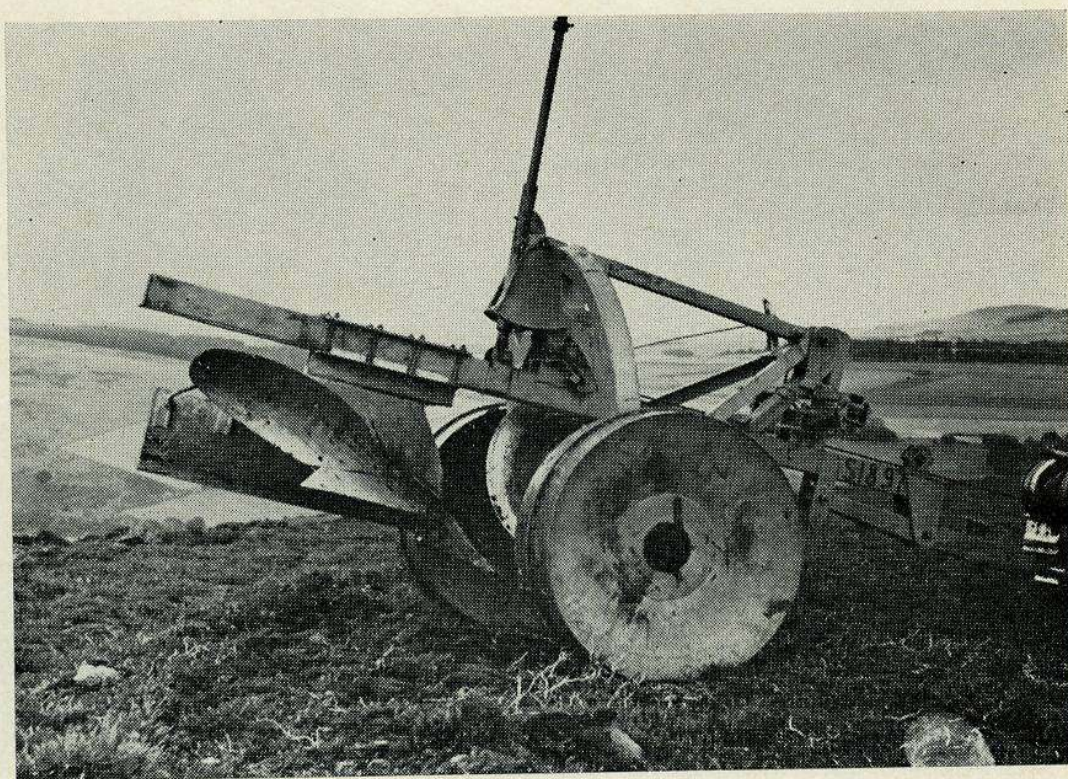
Pl. 9. RLR initially pulled by a CAT D4. (Forestry Commission B6107).



Pl. 10. "Sunshine" or "Sun vertical" stump jump disc plough. (For. Com. C2102).



Pl. 11. "Majestic" 8 disc stump jump plough from Australia. (For. Com. C2528).



Pl. 12. Parkgate tine plough mounted on a Cuthbertson carriage. (For. Com. A362).

stump-jump plough were used on chalk downland but the drying out of the "fluffy" surface even when consolidated by a crawler tractor, and the fast regrowth of weeds militated against them (Wood and Nimmo, 1962). Yeatman's Australian background led to his contacting the firm of Shearer & Sons of Adelaide and after due approval from the Machinery Development Committee, a Shearer Majestic disc plough weighing about two tons was imported in 1954 (Pl. 11). It was tested at Hallyburton (East Scotland), Allerston (Harwood Dale) and Cleveland (Yorkshire) and at Speymouth (Morayshire)). Although its intended role was to provide superficial cultivation as a prelude to subsoiling, its maximum depth was only $8\frac{1}{2}$ inches and as it required a BTD 18 crawler to tow it and much space for turning, it met with no favour among foresters who were accustomed to deeper disturbance at a single pass from normal ploughs. Stewart (1957) described these trials in some detail. Yeatman himself had meanwhile left the scene and hence its systematic use was never furthered, although it worked occasionally (*e.g.* at Speymouth) in 1956 and 1958 and possibly in other areas on loose soils where only scalping or scarification after felling was required. Not until 1973 was further interest expressed in discing when French mechanised systems of "Ligniculture" involving inter-row cultivation were being considered by Research Division staff in the south of England.

The place of the RLR plough in Scotland, from 1951 onwards was overtaken by a tine plough made by Messrs Clark carried on a Cuthbertson carriage. Both single and double mouldboard versions were tested but in general the single one was found most versatile (Pl. 12). The Cuthbertson tine ploughed thousands of acres of Scottish heathlands and was in use in East Scotland until 1961, overlapping in time with the later Parkgate carriage, but outwith East Scotland it was superseded at an earlier date by the Parkgate carriage. On non-indurated mineral soils the tine channel could attain 15 inches depth while producing an 8 inch furrow. Its main snag was the strong side thrust and shock loading from hard stony soils which bent the beam. In any case the Cuthbertson self-levelling device, so valuable in the wetland drainage context, provided no advantage. Whereas on clay soils it could attain design depth, on hard or bouldery areas there was a constant temptation to avoid trouble by riding shallow.

For southern England both on chalk and non-indurated heathlands, where vegetation suppression was a primary aim, Colonel Shaw (FC Machinery Officer) designed in 1953 a light double mouldboard plough having a central sub-soiler which was built by Roadless Traction Limited. (Machinery Development Committee Report No. 22). It was composed mainly of Ransome parts, and mounted on a Fordson half-track tractor. It had user trials at Friston, Abinger and Ascot Forests (Pl. 13), but as it constituted a retrograde step for foresters keen to tackle ever-tougher conditions it was not generally accepted.

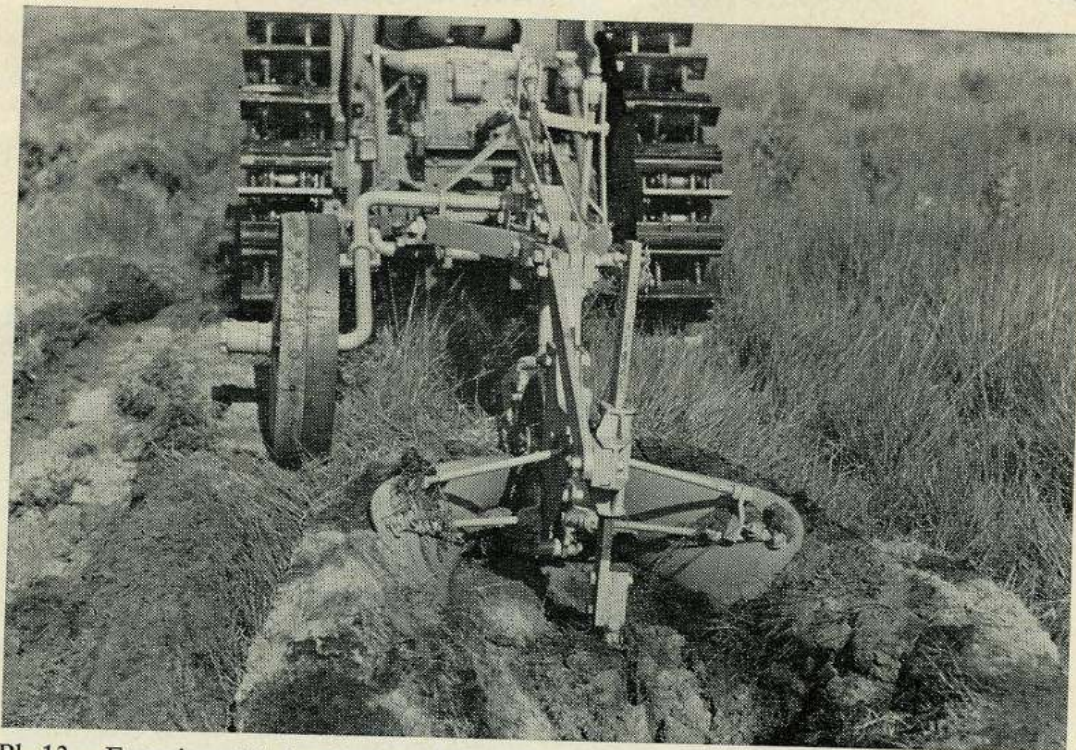
The equipment which simplified the dry ground ploughing problem was the carriage eventually known as the "Parkgate" (Pl. 14). This was designed in 1954 by R. B. Ross (then mechanical engineer in north Scotland) and its production by Messrs Clark of Parkgate was overseen

by J. Blane. Hence for several years it was known as the Ross, Blane, or Parkgate Carriage in different parts of the country until 1957 when an authoritative handbook confirming the latter name was issued by Director (Scotland). This booklet included the earnest hope that "Foresters and operators and others will avoid introducing variation to the design in an endeavour to meet local needs" and although many modifications were suggested by users over the years, these were in the main carried out by Messrs Clark. Although originally a single mouldboard tine plough was used, a double-throw mouldboard was soon offered and the latter could be operated as a sub-soiling tine (by removal of both mouldboards), or as a right or left single mouldboard outfit by removal of one mouldboard, as well as a double-throw tine adjustable to a high or low position. Such moveable mouldboards were originally requested by M. Penistan (Assistant Conservator East Scotland) to provide the facility of deep or shallow tining with corresponding thick or thin turves as required by varying vegetation types. Approximately eight of these were made (W. Clark, Personal Recollection) and were mainly in use in east and south Scotland, and in south west England following Penistan's transfer to that area. This double mouldboard plough was used to achieve complete burying of heather although not strictly complete cultivation, but its use had to be confined to relatively flat terrain and the moveable mouldboards soon had to be welded in to place to achieve rigidity. Variation in tining depth was thereafter provided by substituting a deeper tine point as appropriate.

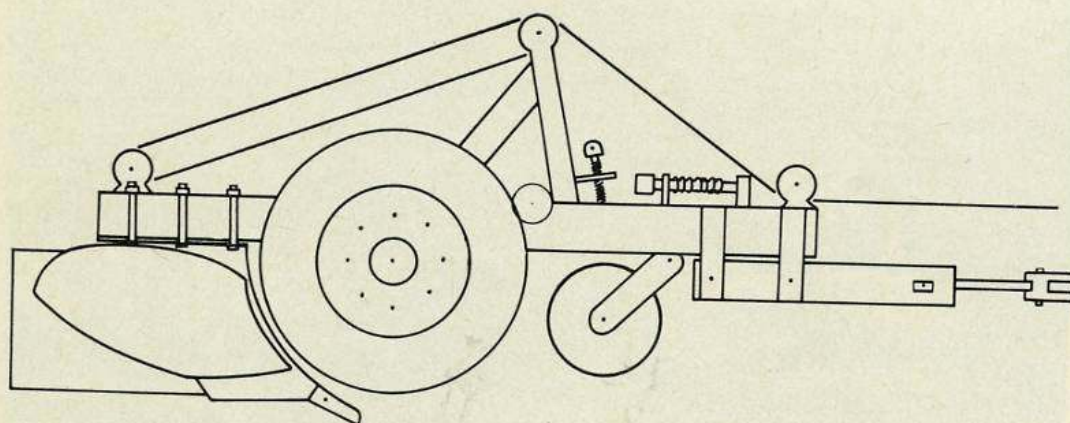
The Parkgate tine plough (Pl. 15) was very well received and by 1960 it was the favourite heathland plough throughout the country, though it had been in use in Scotland for some five or six years previously.

Various improvements were made to the carriage over the years. Among the most important were the substitution of hydraulics for the cable previously used for lifting the plough beam (Pl. 16). The hydraulic ram, apart from avoiding the necessity for a heavy winch at the rear of the tractor also enabled the plough speedily to regain operating depth after being forced out by an obstacle. In practice it provided an efficient means of "floating" depth control to maintain uniform furrow depths. The obvious next step of using Cuthbertson-type mouldboards for wet ground turf production and drainage was taken by 1963 in south Scotland. This Parkgate Universal package (*i.e.* a carriage to which a variety of ploughs could be readily attached on the hill) gradually superseded all other trailed equipment. Extra wheels could be added to improve its flotation on soft ground and in addition two wheel positions were provided to allow either leading or trailed wheels). The latter were preferred for level ground but under the steepest conditions the former position reduced the risk of capsizing. This feature was particularly appreciated in the Tweed Valley where contour ploughing was then favoured, but with the advent of up and down ploughing and greater use of directly mounted ploughs, this choice of wheel position was phased out. It is not mentioned by Taylor (1970).

The main advantages of the Parkgate equipment have been its robust-

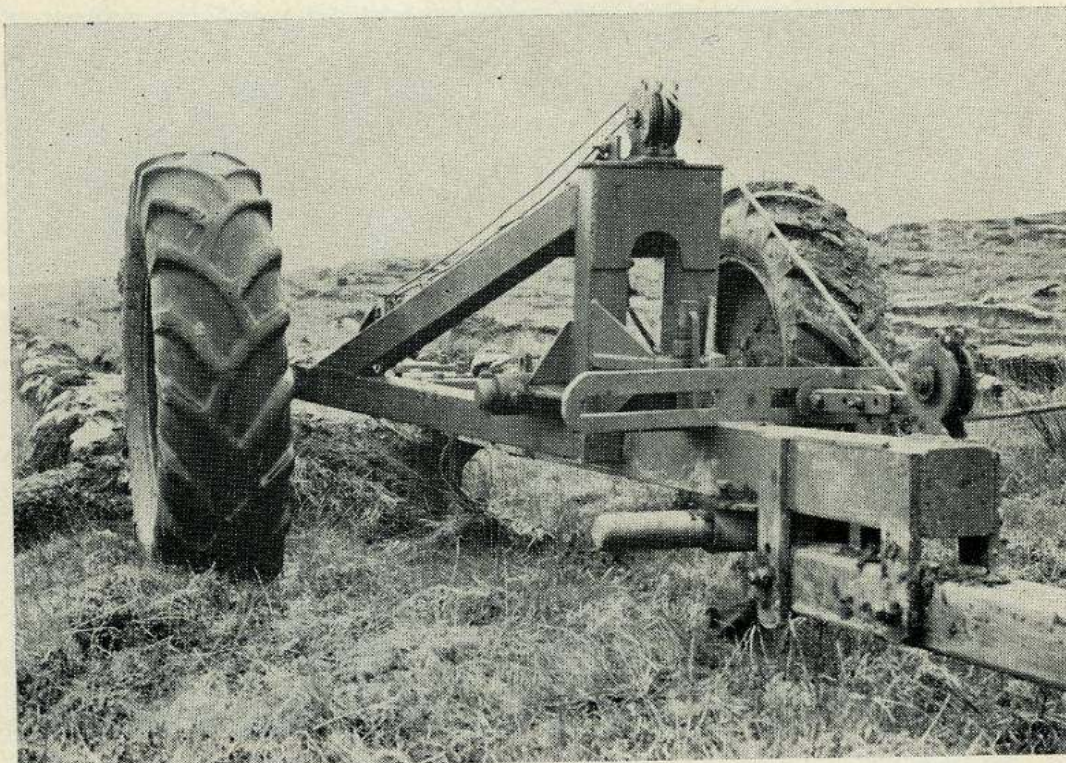


Pl. 13. Experimental double mouldboard plough mounted on a Fordson Major half track. (Forestry Commission D3038).

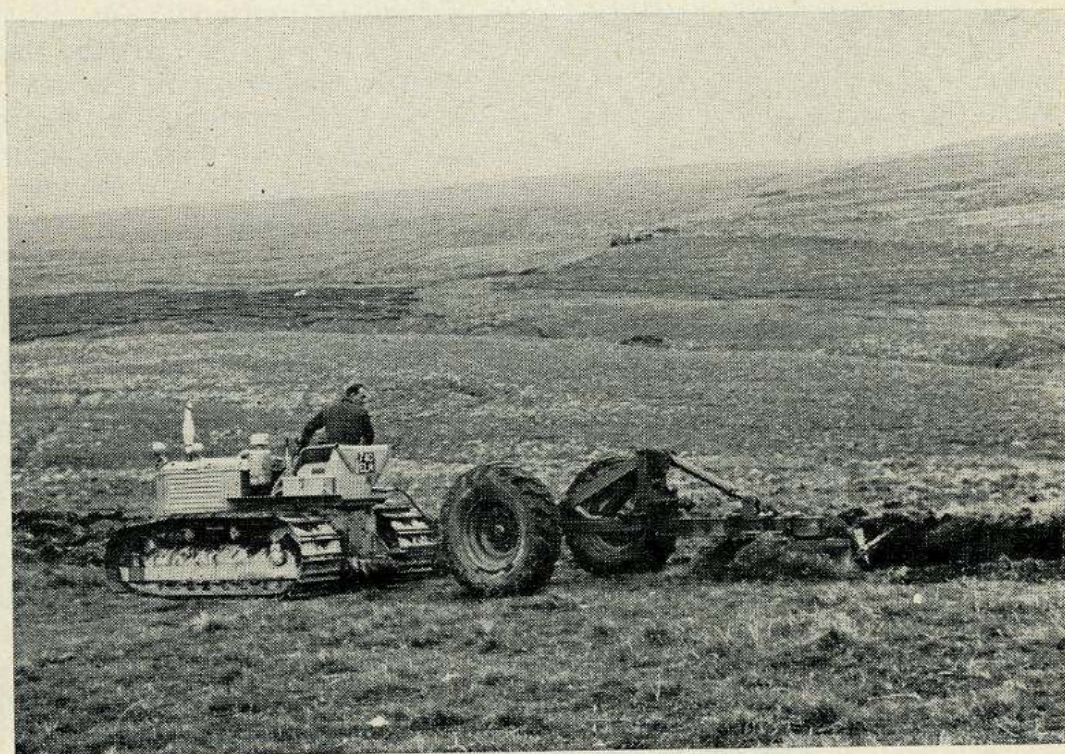


Standard carriage and tine plough.

Pl. 14. Parkgate carriage illustrating the arrangement of drawbar, discs, wheel support frame and plough. (Forestry Commission).



Pl. 15. Parkgate carriage. (Forestry Commission C4062).



Pl. 16. Parkgate carriage. (Forestry Commission A2830).

ness, ease of maintenance and versatility. The wide range of ploughs which have been attached to it are listed below.

1. *The standard single mouldboard plough (Pl. 16)*

First used in about 1954 and continuously thereafter, eventually enlarged to be capable of sub-soiling to a depth of 18-24 inches. In 1964 in Galloway extensive areas of irregular terrain with shallow sub-surface rock were being afforested and to facilitate ploughing the tine was completely removed. Thus turf production was mechanised but longer term site amelioration would, of necessity, remain minimal.

2. *The double mouldboard tine plough (Pl. 17)*

This plough was the final simplified version of the previously mentioned "Penistan moveable mouldboard plough." Its role was not a large one, being properly confined to those areas where weed suppression was of more importance than cultivation—cultivation is of course reduced by the wider spacing of double mouldboard ploughing. It was used experimentally at Teindland (Morayshire) in 1957 and there achieved the unusually good depth of 15 inches.

3. *The twin furrow tine plough (Pl. 18)*

This equipment consisting of two single mouldboards mounted in echelon was developed originally in about 1956 to maximise cultivation at one pass. However it was soon found that it could not operate at design depth and became known as the "fire-trace plough" because shallow ploughing of strips for this purpose became its main function. It was used in a cultivation experiment on a non-indurated glacio-fluvial podzol at Inshriach Forest Inverness-shire in 1961 in comparison with the standard single mouldboard Parkgate tine. The respective depths reached by the tines were 10.7 and 13.7 inches. It is noteworthy that on this relative easy site a Solotrak plough which was resuscitated for the complete ploughing treatment, attained a depth of 15 inches. In 1970 an enlarged version was designed and produced by Messrs Anderson (Mech. Eng. (S)), Taylor (Silviculturist (N)) and Clark of Parkgate, for east Scotland to be used with the heavier Challenger 33 crawler. This is now the standard equipment for complete cultivation of bare heathland sites in east Scotland (Taylor, personal communication).

4. *The twin time (or off-set tine) plough (Pl. 19)*

Following an idea apparently originating in east Scotland (Allison, 1964), this plough was produced in 1963 by the customary triumvirate, in this case J. W. Muddle (Conservancy Mechanical Engineer, south Scotland) R. Swan (Specialist Ploughing Forester, south Scotland) and Messrs Clark. The offset tine sub-soils a channel of 18-24 inches design depth over which is laid the planting turf on the next run of the plough. It had been found earlier that tree roots did not flourish in the tine channel at the bottom of a furrow of very hard soils and that roots even grow upwards from it into the turf above. Thus it was hoped that a tine channel

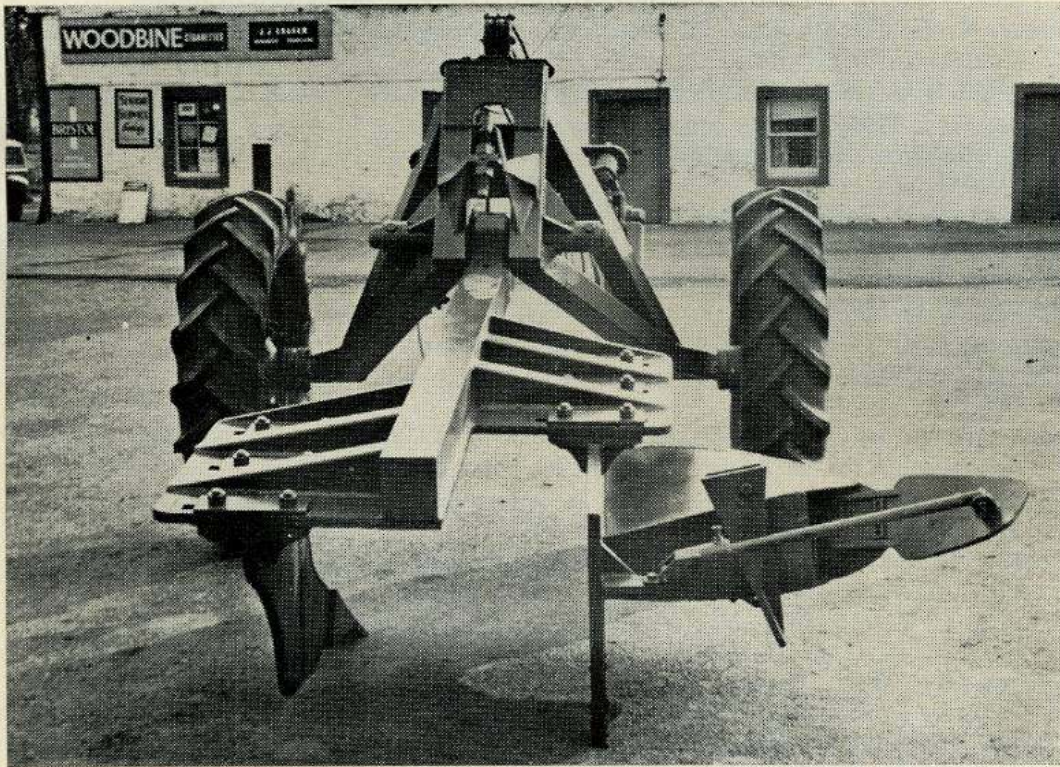


Pl. 17. An early version of the double mouldboard tine plough mounted on a "Universal Carriage." (Forestry Commission A2285).



Pl. 18. The earliest twin furrow plough used for ploughing fire traces in South Scotland. (Forestry Commission).

immediately below the "humus sandwich" would encourage better rooting at depth and consequent improved tree stability. This plough has been particularly favoured in east Scotland where its ability to double the amount of ironpan rupture has been recognised as its particular virtue. A few such ploughs have remained in use on the eastern part of south



Pl. 19. The first twin tine plough with adjustable spacing off-set tine and a normal tine mouldboard. (Forestry Commission).

Scotland where they were further developed by modifications to the tine sock (*e.g.* extra length, wings and bulbous shapes to attain a "moling" action) and increasing overall strength with a second beam. The enthusiasm of M. Long, the local District Officer, fired many of these modifications.

5. *Single and double mouldboard turfing ploughs*

These wetland ploughs are essentially derived from Cuthbertson types F and P and their antecedents are more fully described in chapter II.

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